DISCOVER HOW WE WILL LIVE ON THE MOON

HOW IT WORKS

SC… …MENT TECHNOLOGY … SPACE ™

INSIDE

10 MOST DANGEROUS JOBS IN THE WORLD

THE SCIENCE OF MAGIC TRICKS

How your brain is fooled by the masters of misdirection

FIND OUT

HOW SMARTPHONES KEEP YOU AWAKE

HOW BATS SLEEP UPSIDE DOWN

WHY MUSCLES HURT AFTER EXERCISE

507 INCREDIBLE FACTS:

CANNIBAL GALAXIES EXIST

WOODLICE HAVE GILLS

THE TALLEST TREE TOWERS OVER BIG BEN

RESCUE ROBOTS

REVEALED: THE AI ARMY THAT COULD SAVE YOUR LIFE

CAMERA TECH

Understand the inner workings of any digital SLR

TERRACOTTA WARRIORS

Learn about China's ancient army for the afterlife

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AMAZON EXPLAINED

From order to dispatch, how algorithms run the warehouse

+ LEARN ABOUT ■ EXTREME TRUCKERS ■ BIRD BEAKS ■ VINYL LPS ■ BACTERIA ■ ROCKETS

ISSUE 82

WELCOME

The magazine that feeds minds!

Page 58
Find out why trees are so vital to our survival

Talk of a robot takeover has been gaining momentum. Whether it's lists of jobs they'll be able to perform (I'm safe, I've checked), or the fear that 'thinking' machines could spell the end of humanity, the prospects are pretty gloomy. But maybe a real-life Baymax would change people's minds.

Like the lovable, squishable bot from *Big Hero 6*, there are machines being designed with the sole purpose of saving lives. They will roam across rubble and burst into burning buildings, scooping victims up in their metal arms. But there are a few challenges the rescue robots of the future will have to overcome first. We delve into the nuts and bolts of the issue on page 20.

Perhaps, one day, robots will take the place of humans in the most dangerous professions. In the case of bomb disposal, bots are already lending a hand (page 12).

And the sense of peril doesn't stop there, intrepid reader. We spoke to a real-life ice road trucker who drives across frozen roads for a living, and investigated how humans could eventually colonise the Moon. I'll take a desk job any day...

Jodie

Jodie Tyley
Editor

Meet the team...

Jo
Features Editor
I struggle with mild English winters, so a life on the ice roads is definitely not for me. Hats off to the brave extreme truckers surviving in -50 degrees Celsius!

Jackie
Research Editor
Ground Control to Major Tom. Commencing countdown, engines on... Turn to page 74 to see how NASA's SLS compares to other rockets through history.

Katy
Production Editor
Magicians have been playing with our perceptions for centuries, but the young field of neuroscience is starting to catch up. Our brains are so easily misled!

Duncan
Senior Art Editor
I'm already saving for my ticket to the Moon. I want a good Earth view from my hotel window too. Will lunar holidays actually happen in my lifetime?

Briony
Assistant Designer
As we reach the end of Dry January, it seems only fitting to throw in not one, but two beer articles. Turn to pages 80 and 94 to find out more.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

What is the physics behind a golf swing? **Page 55**

How do natural sinkholes form? **Page 64**

How does live traffic data work? **Page 42**

How does a gas stove ignite to cook your dinner? **Page 26**

How do cannibal galaxies eat smaller ones? **Page 75**

How did beer develop through the ages? **Page 80**

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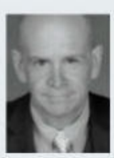
Meet the experts…

Laura Mears
Could we live on the Moon? How would we do it? And why would we want to? Laura tackles all the big questions about this intriguing topic and explores the tech that could someday make lunar living a reality!

Ella Carter
This month, animal expert Ella explains why trees are so integral to both humans and wildlife. She also reveals some surprising facts about woodlice and the amazing world of cenotes.



Stephen L Macknik
Best known for his studies on illusions, consciousness and attentional midirection, neuroscientist Stephen co-wrote this month's fascinating feature about magic tricks.

Susana Martinez-Conde
Award-winning neuroscientist and co-author of *Sleights Of Mind*, Susana explains how magicians misdirect our attention.

Ceri Perkins
Science writer Ceri counts down ten of the most dangerous jobs on the planet and looks at the innovative tech that's helping to make these professions a little safer.

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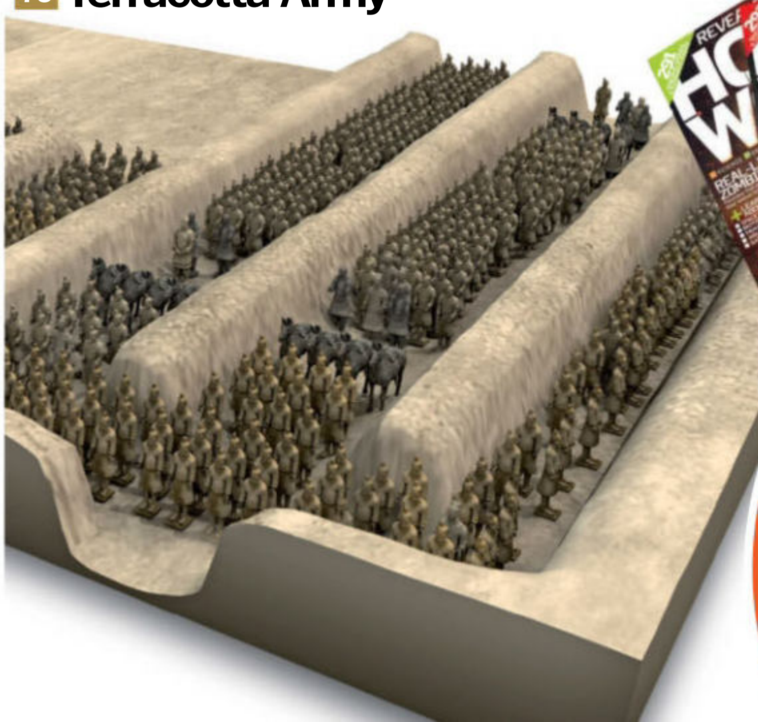
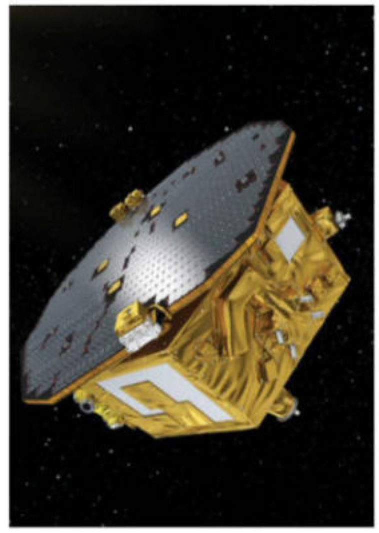


REGULARS



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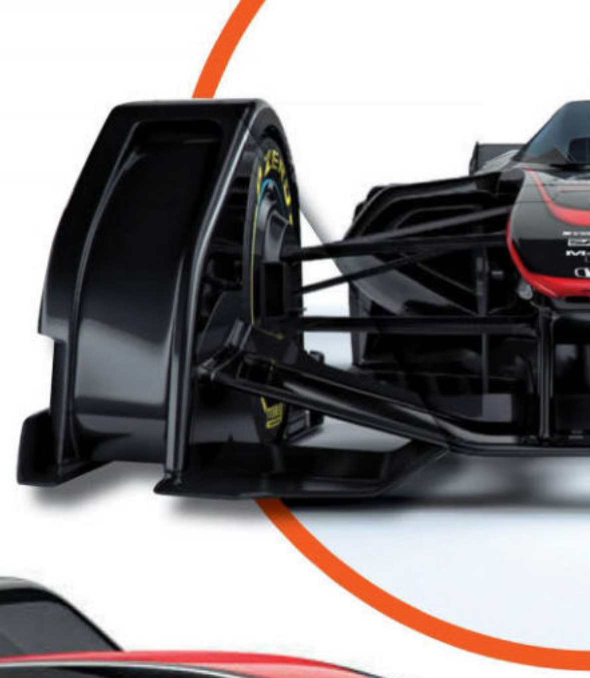


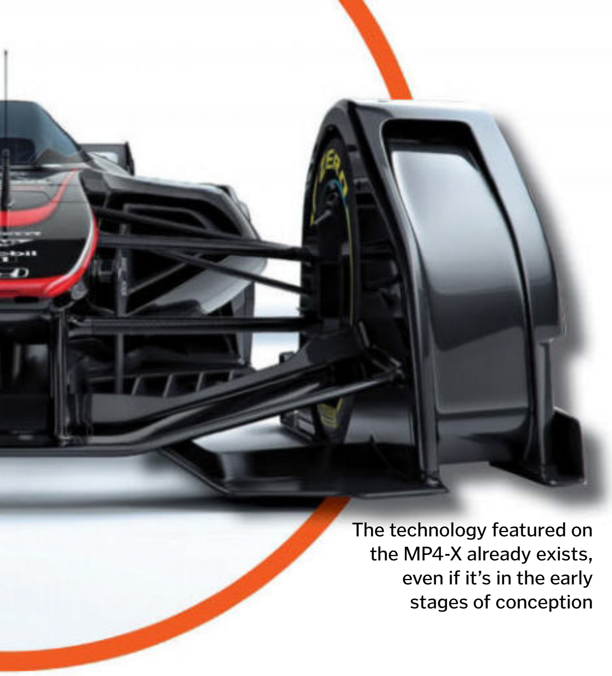
The future of Formula One

McLaren's new concept car can be controlled by the driver's brain

When designing the MP4-X concept, McLaren's engineers completely ripped up the rulebook, kitting out the futuristic car with a morphing chassis and vehicle systems operated by the driver's brain patterns. Higher top speeds can be reached thanks to electrodes fitted to the surface of the car's wings. When switched on they can turn the surrounding air into plasma, increasing the down force on the body for better cornering.

Stopping to refuel could also become a thing of the past, as this hybrid vehicle would be able to recharge through inductive coupling built into the track, and receive a power boost from solar panels mounted on the bodywork. The energy can be stored in several thin batteries integrated into the vehicle's structure, making electricity available close to wherever it is needed.

In the garage, the team would be able to monitor the car's tyres and structural condition in real-time while it's on the track, helping to prevent any accidents. However, in the event of a crash, the 'negative-stiffness' material used to construct the body would reduce the force of impact and then instantly recover to its original shape, so the driver could stay in the race, and their risk of injury would be reduced.



The technology featured on the MP4-X already exists, even if it's in the early stages of conception

Mind control cars

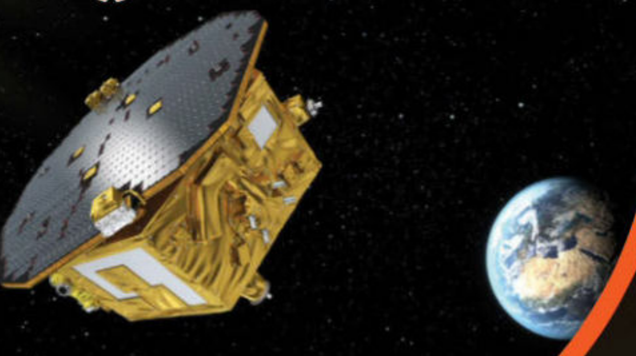
The next generation of racing drivers could sit in fighter-jet style cockpits, using mind control instead of their hands to steer around the track. Electrical patterns within the driver's brain are used to operate the main controls, while sensors constantly monitor their levels of fatigue, hydration and focus to enable better race planning.

The cockpit itself is completely enclosed for added safety, but cameras all around the car feed live footage to a display in the driver's helmet, giving them an unrestricted 360-degree view of their surroundings. The display also provides the driver with sensory cues alerting them to useful information such as the position of their closest competitors and the location of accidents.

If they are unlucky enough to be involved in a crash themselves, their race suit will detect and highlight areas of impact trauma to assist the medical teams that come to their aid.

The driver's cockpit, helmet and race suit have all had a high-tech upgrade

The McLaren MP4-X is a futuristic concept utilising hybrid power systems and other emerging technologies



LISA Pathfinder cannot itself detect gravitational waves, but will test technology for future detectors

Einstein's theory is put to the test

The European Space Agency launches a mission to look for space ripples

In his Theory of General Relativity, Albert Einstein predicted that masses accelerating in space – such as exploding stars – cause ripples in space-time known as gravitational waves. While indirect evidence of their existence has been observed, Earth-based methods for directly detecting gravitational waves have so far proved unsuccessful, so scientists are hoping to study them in space instead. The LISA Pathfinder spacecraft launched on 3 December 2015, and will spend three months travelling 1.5 million kilometres away from Earth. It will then be used to test the technologies needed to detect gravitational waves, paving the way for an even bigger mission in the 2030s.

Being able to detect gravitational waves will help scientists better understand the universe

It would take the average person 40 minutes to walk around the FAST Telescope

The world's largest radio telescope

China's enormous telescope will scan for signs of alien life

Nestled in a rock basin in China's Pingtang County, the Five-hundred-meter Aperture Spherical radio Telescope (FAST) is undergoing the final stages of its construction.

With a dish the size of 30 football pitches, the telescope will be able to pick up radio signals from billions of light years away, helping us search for distant galaxies and listen out for extraterrestrial life. Once it is completed in September 2016, the telescope will also be able to scan twice as much sky as the current largest radio telescope, the Arecibo Telescope in Puerto Rico.

Hold me closer, tiny dancer: peacock spiders bust a move for a date

Peacock spiders dance for love

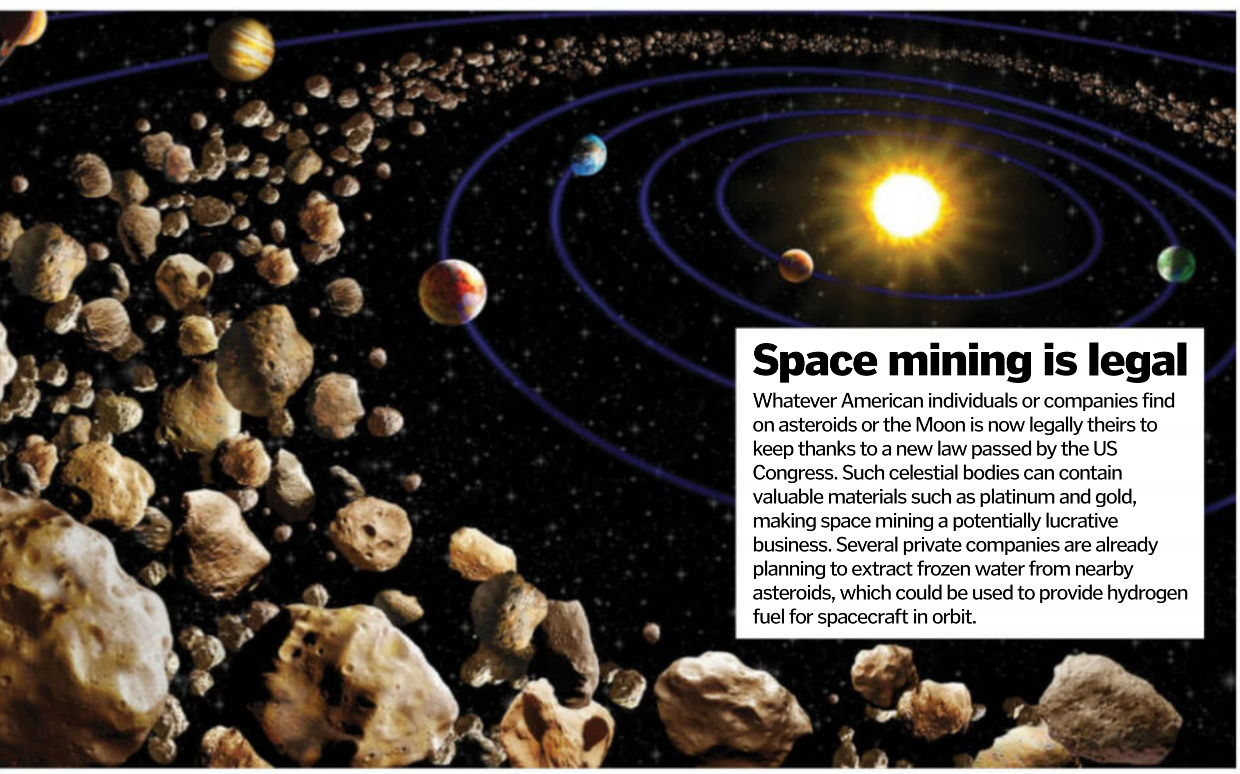
Dance routines and colourful displays help male spiders woo the ladies

To explain the complex mating rituals of the animal kingdom, scientists from the University of California and the University of New South Wales have turned to the tiny peacock spider for help. By studying the males' bizarre vibrating and leg-waving routine around the opposite sex, they found that the spiders that put in the most effort and paid more attention to the female's reactions had a better chance of attracting a mate. This has led them to believe that the females' picky nature is what has caused the courting males to evolve such behaviour.

GLOBAL EYE
10 COOL THINGS WE LEARNED THIS MONTH

Penguins eat snow to cool down

In order to survive the extreme cold and winds of Antarctica, penguins often huddle together to keep warm. However, researchers have now discovered that they can get too warm, with the air inside the huddle sometimes reaching an uncomfortable 37.5 degrees Celsius. They believe this is why huddles never last very long, and why some penguins have been spotted eating snow to cool down afterwards.



Space mining is legal

Whatever American individuals or companies find on asteroids or the Moon is now legally theirs to keep thanks to a new law passed by the US Congress. Such celestial bodies can contain valuable materials such as platinum and gold, making space mining a potentially lucrative business. Several private companies are already planning to extract frozen water from nearby asteroids, which could be used to provide hydrogen fuel for spacecraft in orbit.

There's a phone you can wash with soap

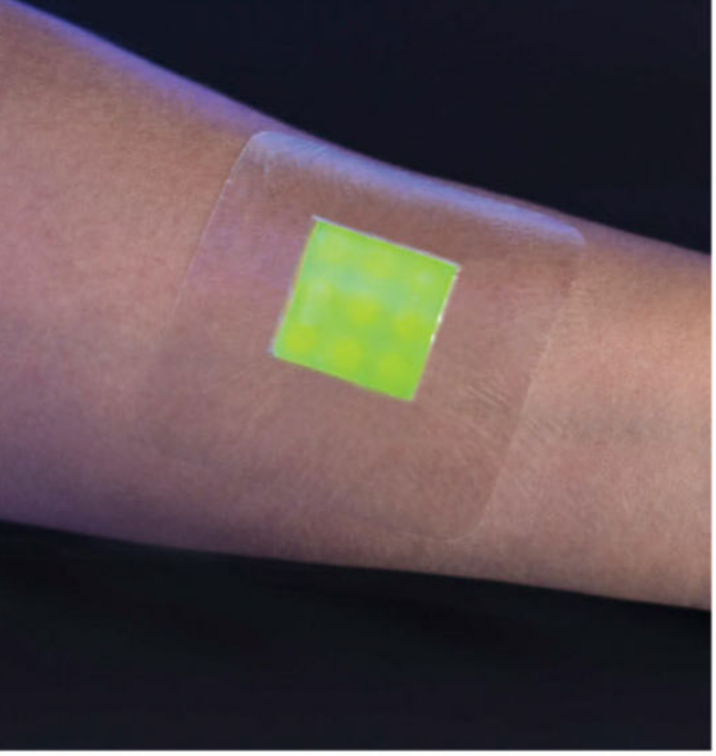
Japanese company Kyocera has invented the world's first washable smartphone, complete with a special touchscreen that works when wet. The Digno Rafre is also dustproof and shock resistant and has smart sonic receivers that prevent the speakers from being damaged by water.

Stonehenge may have been built in Wales

A team of archaeologists have found the exact location from which Stonehenge's 'bluestones' came from. They now believe the stones were first used to build a monument near to the quarry in the Preseli Hills, Pembrokeshire, and hope by finding it they can finally reveal why and how Stonehenge was built.

There's no such thing as a male or female brain

While specific parts of a human brain can reveal the owner's gender, researchers from Tel Aviv University, Israel, have found that most have a mixture of male and female traits, making them impossible to categorise. By studying brain scans of 1,400 different people they found that very few had all of the brain features expected for their sex, and that the overall structure of men and women's brains is the same.



A glowing bandage could show infections

Burn wound infections are very common and sometimes fatal, but also difficult to diagnose. Doctors often treat the patient with antibiotics as a precaution, which can contribute to antibiotic resistance. A new smart dressing changes colour as soon as an infection is detected, helping doctors know if treatment is needed and letting them respond quickly.

Life-extending genes have been discovered

After researching the genomes of worms, zebrafish and mice, scientists have found genes that influence ageing. By blocking one of these genes they could extend the lifespan of the worms by up to 25 per cent, and believe the same could be done in humans.

A commercial jet will launch satellites into space

Virgin Galactic is going to use an old Boeing 747-400 aircraft, nicknamed 'Cosmic Girl', as a rocket launch platform. The aircraft will have the LauncherOne satellite delivery rocket mounted underneath its left wing. When it reaches the required altitude, the rocket will then be released and its engines fired, sending it into orbit.

Chewing gum can be turned into sensors

After chewing a stick of gum for 30 minutes, researchers at the University of Manitoba, Canada, cleaned it in ethanol and then added a solution of carbon nanotubes. As these tiny carbon molecules can conduct electricity, they turned the gum into a bendable medical sensor that could provide a cheaper and more flexible alternative to the metal sensors currently used in wearable devices.

Cockroaches communicate using poo

Rather than making friends at parties or down the pub, cockroaches use their poo to help them find like-minded pals. Researchers at North Carolina State University have found that bacteria in the cockroach's gut produces a variety of fatty acids which in turn produce pheromones. These provide a 'welcoming scent' to other roaches, helping them gather together.

TEN MOST DANGEROUS JOBS IN THE WORLD

+ HOW SCIENCE AND TECH ARE MAKING THEM SAFER

01 Bomb disposal expert

The ice cool engineers who put their lives on the line

Demanding raw courage, composure, and hands as steady as stone, explosive ordnance disposal (EOD) is the ultimate nerves-of-steel occupation. The elite engineers who take on this important work override all their natural self-preservation instincts as they approach and attempt to neutralise deadly packages like car bombs, improvised explosive devices (IEDs) and land mines.

Officials are wary of releasing fatality figures, but most EOD operatives know at least one colleague killed in the field, and the majority have had a close call of their own.

Still, there are a handful of technologies that make their work a tiny bit safer. Small robots are often sent ahead to scout out the nature of the threat, for example. Some are even equipped to disarm bombs themselves, but there is usually no substitute for the steady hand and quick wits of a seasoned human expert.

When they do go in, EOD technicians are covered by an Electronic Counter Measures operator who uses signal jammers to prevent enemies detonating radio-controlled IEDs. Finally, they don a special blast-resistant suit made of tightly woven Kevlar fibres and packed with a hefty 35 kilograms of high-density foam and ceramic ballistic plates.

It's important their hands are left exposed so they can perform delicate work

EOD technicians put their lives at risk to prevent civilian casualties

Bomb disposal suit

The gear that resists flying shrapnel and blast waves that could purée internal organs

Helmet
Bulletproof layers of aramid fibre lined with shock-absorbing foam prevent blunt trauma to the skull.

Collar
This completely encloses the neck and overlaps with the helmet to protect against blast pressure.

Blast plates
Rigid ballistic panels are arranged to protect the throat, torso and groin, resist flying shrapnel and shield the body from pressure.

Jacket
Constructed from Kevlar with a flame-retardant cover, the jacket incorporates an articulated spine protector in case the wearer is floored.

Ventilation and communication
A forced air ventilation system, de-mister and communication electronics can operate continuously for up to five hours.

Cooling system
Ice water is pumped around a network of capillaries sewn into the inner fabric, to combat overheating.

Control module
This allows the wearer to control the helmet functions and communication system.

Trousers
Braces with quick-release buckles hold up the trousers; the back of each leg features a full-length zip for rapid removal in a medical emergency.

"The elite engineers override all natural self-preservation instincts"

8-10 YEARS OF TRAINING REQUIRED TO BECOME A HIGH-THREAT EOD TECHNICIAN

02 Firefighter

The heroic first responders who can take the heat

56% OF US FIREFIGHTER FATALITIES IN 2014 WERE CAUSED BY CARDIAC OVEREXERTION

Sprinting towards – rather than away from – burning buildings is pretty much the definition of a dangerous job. The brave men and women who dedicate their lives to quashing blazes and rescuing trapped victims face a whole host of well-known hazards, including smoke inhalation, burns, collapsing structures, and falling debris.

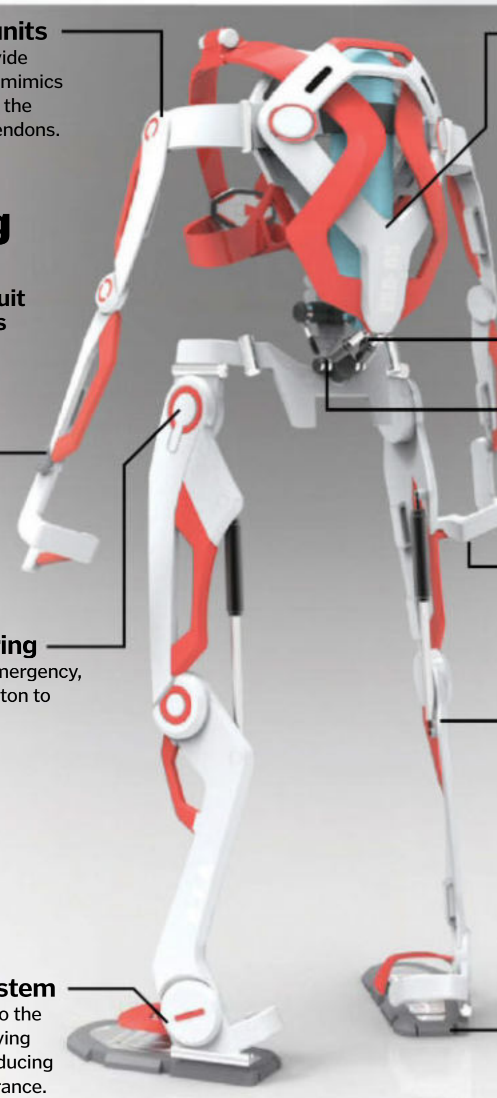
Science and technology has offered firefighters many ways to improve their safety over the years – from detailed studies of how different kinds of fires propagate to portable breathing equipment, and from night-vision goggles to clothing made from flame-retardant materials. In just the last couple of years, a wireless digital positioning shoe antenna was invented to help rescue coordinators track the locations of individual firefighters in perilous situations.

Design student Ken Chen became especially concerned about fires in high-rise buildings, where people can quickly become trapped out of reach of ladders and equipment on the ground. In these cases, firefighters must run up and down stairwells in their 40 kilograms of gear, potentially carrying incapacitated victims too.

Chen designed a responsive exoskeleton to increase firefighters' performance in walking, running and carrying. Worn over the top of their usual gear, the exoskeleton delivers power and superhuman strength to the firefighter's limbs, helping them to work faster and longer without becoming exhausted.

Firefighting exosuit

The super-powered suit that helps firefighters run, climb and carry



Power and sensor units
Actuators at the joints provide responsive assistance that mimics and enhances the action of the firefighter's muscles and tendons.

Tool holder
Specialised apparatus can be mounted onto the exoskeleton, such as an impulse water gun or a 'jaws of life' rescue tool.

Quick-release pull-ring
This releases joints in an emergency, causing the entire exoskeleton to disassemble and collapse.

Energy recovery system
Energy that is usually lost to the ground is recovered, supplying extra power to the joint, reducing strain and increasing endurance.

Battery pack
The lithium-polymer battery lasts up to two hours and uses several cells in parallel to increase the current discharge capacity.

Oxygen bottle
An essential air supply is integrated into a smart, load-bearing pack.

Centre connector
Powered by hydraulic cylinders, this transfers weight to the ground instead of to the wearer.

Joystick control
The wearer has one-touch triggering and fine control over tools like the impulse water gun.

Pack frame
The controlling computer module and flash lights are housed in a pack frame. It is designed to bear and redistribute the weight of gear, including breathing apparatus and a rescue kit.

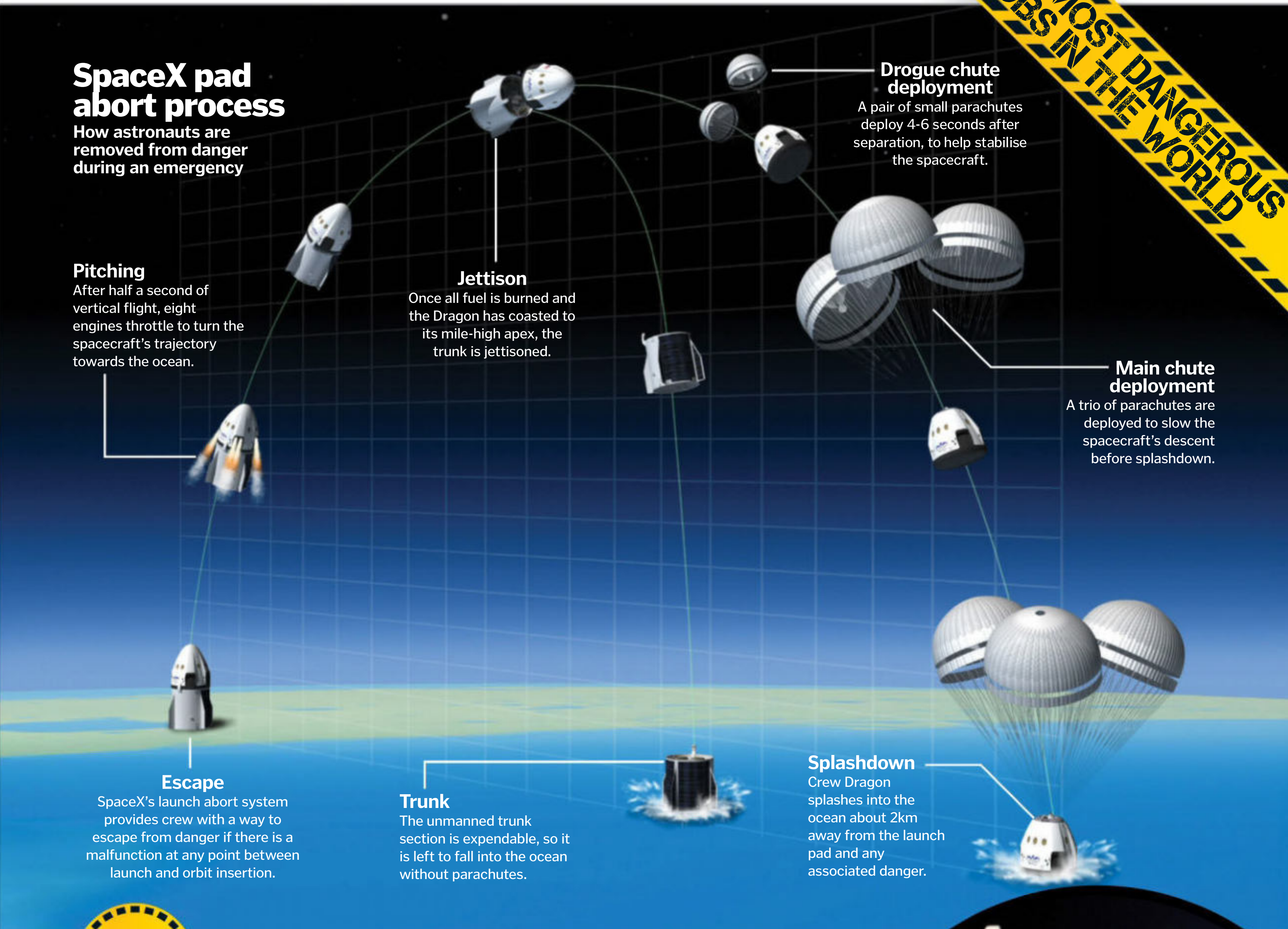
Weight transfer system
The suit is designed to make weight transfer from heel to toe less physically demanding, helping the fighter to propel themselves forward.

The exoskeleton is built to carry specialised kit, including water guns and rescue tools

Walking into a blaze wearing the exoskeleton, firefighters are stronger and safer

SpaceX pad abort process

How astronauts are removed from danger during an emergency



03 Astronaut

One of the most dangerous vocations on – or off – Earth

32 OF OVER 500 ASTRONAUTS HAVE DIED DURING MISSIONS OR IN TRAINING

Most people forget about astronauts when they think of dangerous jobs, perhaps because so few people have ever actually held the position. But the fatality rate for astronauts is, well, astronomical: statistically, a staggering five per cent die – making the profession about 10,000 times more dangerous than the average UK job.

Contrary to what many sci-fi films would have us believe, the biggest cause of death isn't aliens or becoming untethered on a space walk. Only three people have ever actually died in space, and they were aboard a ship. Statistically more deadly are the moments of launch and re-entry into Earth's atmosphere – risks that are reduced with rigorous abort sequences and spacecraft thermal protection systems.

Pressurised spacesuits include up to 14 layers of material to insulate the wearer from extreme temperatures in space, which fluctuate from 120 to -150 degrees Celsius. Sensors within the suit monitor the astronaut's vital signs and beam the information to Ground Control.

Spacewalking astronauts are constantly tethered to their spaceship with a long line, plus several smaller, back-up tethers. But in case of an almighty mishap, they also wear a mini jetpack that is able to scoot them safely back to the ship.

Canadian astronaut Chris Hadfield says his biggest fear is "floating off into space"

> "Being an astronaut is about 10,000 times more dangerous than the average UK job"

Forest harvester

These heavy-duty tree-felling machines make logging safer and swifter

04 Lumberjack

These hardy folk grapple with some of nature's largest creations, in unpredictable conditions

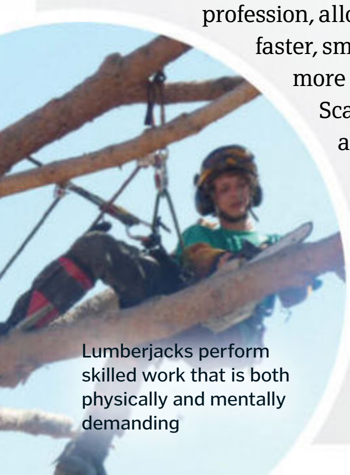
"I'm a lumberjack and I'm okay, I sleep all night and I work all day!" So goes the song. But lumberjacks – whose occupation is officially the most dangerous in the US – have few guarantees of being okay.

Logging is strenuous work, carried out in remote areas among often-treacherous terrain. In 2014, 110 out of 100,000 logging workers were killed on the job, and thousands of others sustained serious injuries. Falling trees, steep and slippery ground, fast-moving machinery and volatile mountain weather are just some of the hazards lumberjacks face.

But new technology is revolutionising the profession, allowing loggers to work faster, smarter and – crucially – more safely. In some Scandinavian countries, almost all logging is now performed using heavy-duty machines that place the operator in a reinforced cab and at a safer distance.

Elsewhere, phone and tablet logging apps feature satellite imagery, GPS tracking, warnings about hidden topographic dangers and severe weather alerts – helping lumberjacks to make sensible decisions and stay safe.

30% MORE LIKELY TO DIE ON THE JOB THAN THE AVERAGE AMERICAN



Lumberjacks perform skilled work that is both physically and mentally demanding

Harvester head

The tools that break down trees

Delimbing knives
These structures reach around the cut tree and strip its branches as it passes through the device.

Feed rollers
The rollers grip the tree and drive it through the delimbing knives.

Chainsaw
This tool fells trees and cuts the lumber into shorter segments.

05 Sea fisherman

The rugged seafarers who spend their working lives at the mercy of a cruel ocean

A life on the ocean waves might sound romantic, but commercial fishing is not for the faint of heart. Ranked as the most dangerous job in the US as recently as 2012, it now occupies the number two spot. Crabbers working in Alaska's fertile but lethal waters endure backbreaking lifting, furious weather, icy decks, rogue waves and the constant risk of being swept overboard.

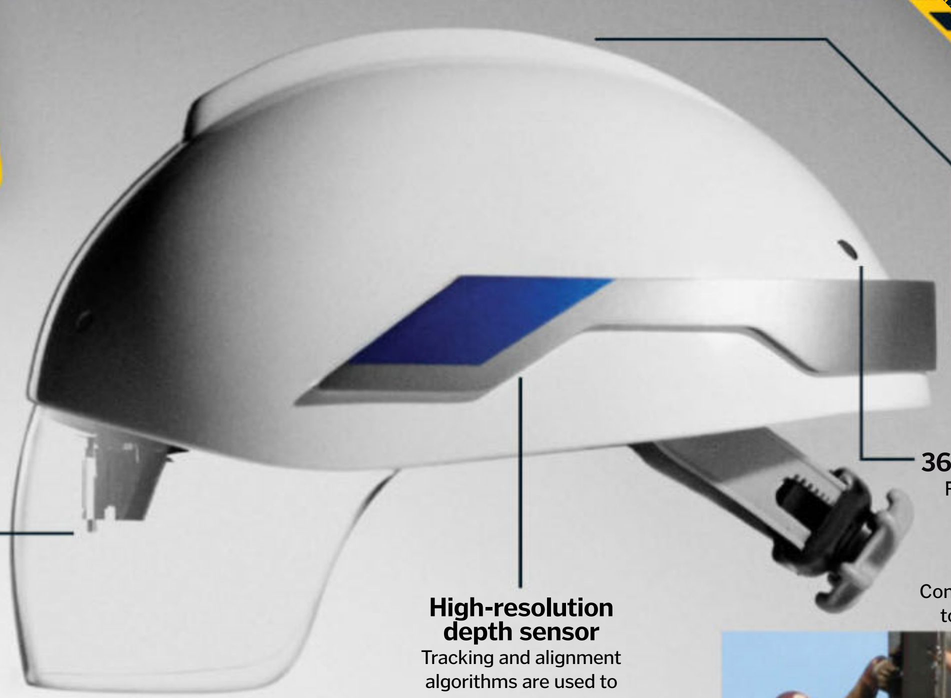
Today, mobile phone apps bolster the modern fisherman's chances in this ancient elemental struggle, by alerting them to approaching storms and perilous wave conditions, or by mapping the precise locations of underwater obstacles like oil and gas pipelines.

"Crabbers endure furious weather, icy decks and rogue waves"

Colossal waves and merciless weather mean many fishermen lose their lives to the sea

80% OF FISHER FATALITIES ARE CAUSED BY DROWNING OR HYPOTHERMIA

39.9% OF US CONSTRUCTION DEATHS WERE DUE TO FALLING IN 2014



Smart helmet

The most advanced headwear in construction layers virtual safety content over the real-world environment

4D augmented reality display
The display is retractable, transparent and readable in both low and bright light.

High-resolution depth sensor
Tracking and alignment algorithms are used to interpret camera data.

Intellitrack unit
An industrial-grade inertial measurement unit tracks where the helmet is in space.

360° multi-camera array
Four HD cameras support video recording, 3D mapping and alphanumeric recognition.

Construction workers can't afford to lose focus, even for a second

06 Construction workers

The skilled tradesmen who have to watch their step

Remember that iconic 1930s photograph of New York City workmen lined up on a steel girder, munching their lunches 250 metres above the ground? It's the perfect illustration of an inescapable hazard of construction: height. A slip several stories up is likely to be much more serious than one at ground level. And the perils don't end there.

Construction workers do heavy labour in all kinds of weather and are at constant risk from the 'fatal four': falls, being struck, electrocution, and getting crushed between objects. It's no surprise that construction accounts for the largest number of workplace fatalities in the UK.

But site workers are getting tech-savvy. Phone apps help with tasks such as safe ladder positioning; smart jackets can warn wearers and vehicle drivers when the two get dangerously close; GoPro cameras are used to document safety walk-throughs; sensors can alert workers to electrocution risks before they touch a live wire; and site safety managers are able to keep an eye on sensor-laden crew on real-time risk monitoring dashboards.

07 Stunt double

The daredevils who risk life and limb for our entertainment

Danger is the first line of their job description. Stunt doubles leap through fire, throw themselves out of windows and drive cars off cliffs so that their celebrity actor counterparts don't have to.

The nature of these stunts has changed little over the years. If anything, audiences' appetites for bolder, more thrilling action sequences have only made the job riskier. Science and technology can offer a helping hand, though.

Safety harnesses and wires are digitally erased in the editing room; pyrotechnicians predict and control explosions; impact protection clothing guards against cuts and bruises (at least for male doubles, who are generally spared the skimpy costumes); and hazards can be added or amplified with CGI.

20-40 PEOPLE KILLED OR SERIOUSLY INJURED DURING FILMING ANNUALLY

Daniel Craig's stunt double performs a helicopter fight scene for the latest James Bond film, *Spectre*

2.4X US COAL MINERS TAKE MORE THAN DOUBLE THE AVERAGE NUMBER OF INJURY DAYS THAN OTHER PRIVATE SECTOR WORKERS

08 Coal miner

One of the toughest jobs imaginable takes place deep underground and surrounded by danger

Humans have used coal for thousands of years and it remains a vital natural resource, generating 40 per cent of the world's electricity. However, extracting the almost 9 billion tons that we burn through each year can be deadly.

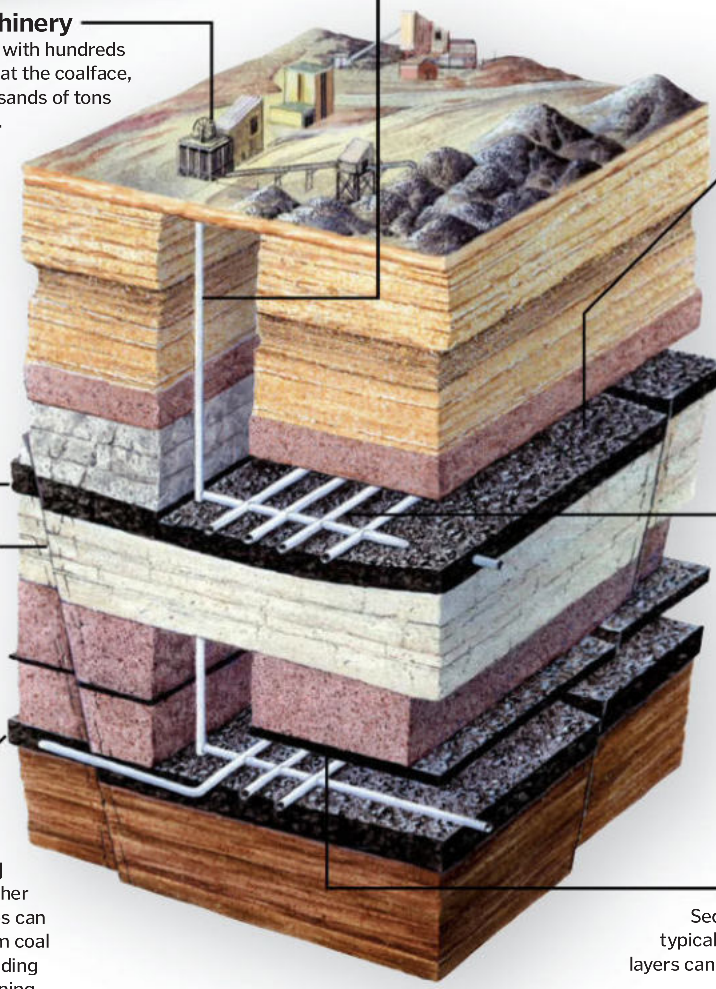
Miners work hundreds of metres below ground, where conditions are hot, cramped, dark, dirty and dangerous. Small train cars rattle through a maze of tunnels to transport the workers to the coalface, often miles from the mine's entrance. The hazards in this underworld include fire and explosion, asphyxiation by poisonous gases, drowning in a mine flood, ill health caused by inhaling coal dust, accidents with monster machinery, and – last but not least – the entire mine collapsing.

In the past, miners carried canaries with them to detect poisonous but odourless gases like carbon monoxide and methane. In the presence of these gases, the songbird – with its tiny lungs – would perish quickly, warning the miners to make a hasty exit.

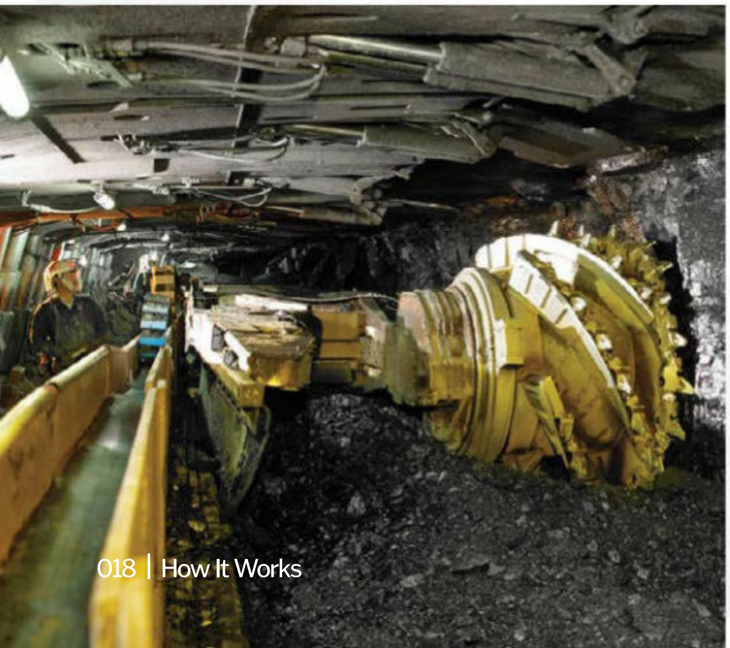
Today, electronic gas meters and alert systems have replaced the birds; resistivity detectors 'peer' through rock to pick out potentially threatening underground bodies of water; and techniques have been developed to dilute methane emissions prior to mining, significantly reducing the threat of methane explosions. Despite these advances, thousands of miners still die at work annually, especially in developing countries.

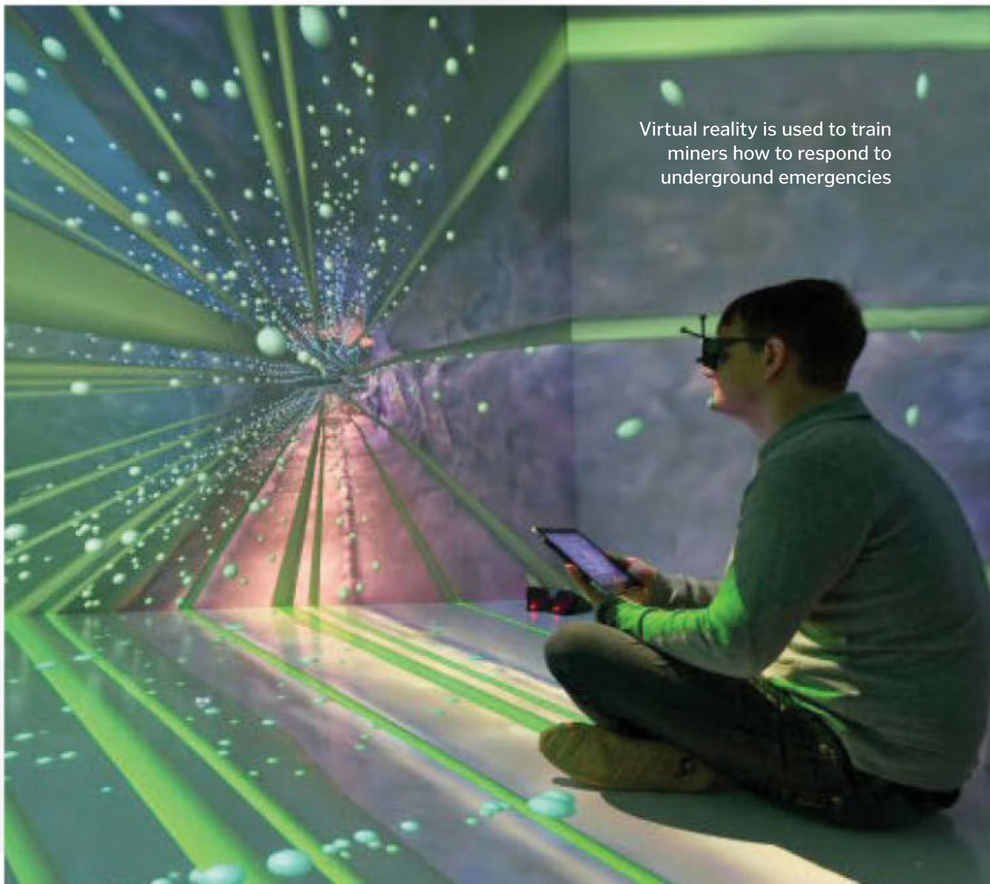
Anatomy of a coal mine

What makes coal mines such dangerous places to work?



A longwall shearer can smash an incredible 5,000 tons of coal from the seam per hour





Virtual reality is used to train miners how to respond to underground emergencies

An underwater welder's equipment must all be properly insulated

09

Underwater welder

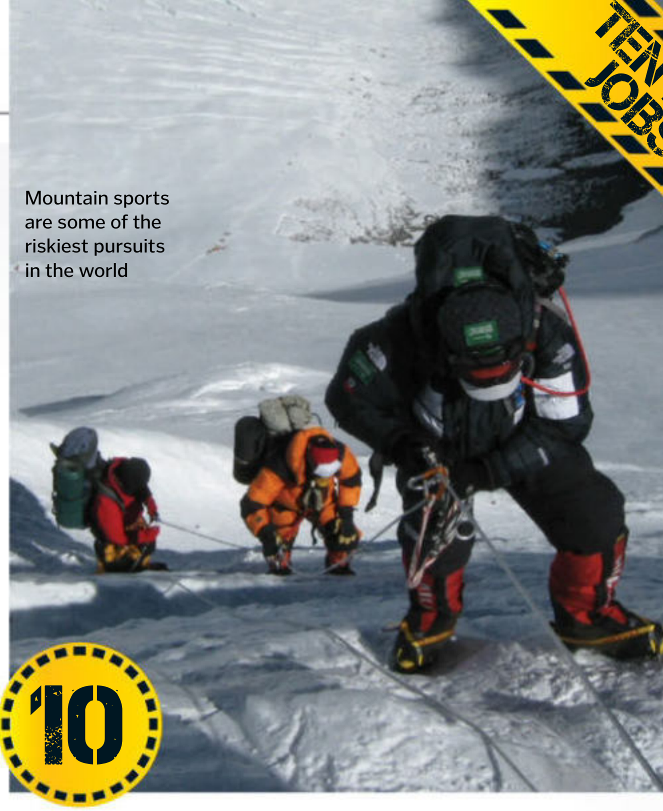
Electricity and water are a deadly combination

Underwater welders are specialised engineers who perform repairs on submerged structures like bridge supports and offshore oil rigs. Their work involves a unique and deadly cocktail of hazards, including electric shocks, drowning, hypothermia, explosions, marine life attacks and the bends.

During wet welding, technologies like protective rubberised dry suits and insulated electrodes reduce the risk of electrocution. A second option – dry welding – involves building a sealed enclosure around the work site, pumping it full of pressurised air, and working within it as if on dry land. However, this is not without its own risks; if concentrated pockets of oxygen and hydrogen develop around the electrical arc created during welding, the results can be explosive.

Despite the work itself being fraught with danger, underwater welders are statistically most likely to die from common diving-related incidents like drowning, nitrogen narcosis or decompression sickness. These threats are managed to some extent using remote surveillance cameras that monitor workers from the surface, and by watching out for malfunctioning gear and signs of distress.

15% FATALITY RATE OF UNDERWATER WELDERS IN 2012



Mountain sports are some of the riskiest pursuits in the world

10

Mountain guide

Experts help others stay safe in some of Earth's most daunting outdoor environments

There's a reason why people hire mountain guides. With jagged rocks, tricky traverses, exposure to the elements and low oxygen at altitude, mountains are dangerous places to be.

Expert mountain guides venture into hazardous back-country again and again, significantly upping their risk of being caught out in freak accidents like avalanches. There is no stopping these violent snow-slides, but technology can increase the chances of surviving one.

The Avalanche Airbag System uses rapidly inflated floats to buoy the wearer to the surface of the churning snow and prevent deep burial. An AvaLung sling can extend the time buried victims are able to breathe under the snow, and a transceiver will emit radio pulses that rescuers can detect from above.

150 ANNUAL DEATHS DUE TO AVALANCHES WORLDWIDE

AvaLung

The essential kit that extends avalanche burial survival time from 15 to 60 minutes

RESCUE ROBOTS

REVEALED: THE AI ARMY THAT COULD SAVE YOUR LIFE

DID YOU KNOW? *Search and rescue bots were used in response to 9/11, Hurricane Katrina and the Deepwater Horizon oil spill*

Imagine the scene after a huge earthquake or natural catastrophe, such as the devastating events in Fukushima or Haiti. An injured victim is buried underneath the wreckage. After some jostling, a spotlight pierces the darkness, the sound of hydraulics and motors approaches, and the rubble is lifted safely clear by a rescuer who isn't even human.

Advances in robotics are making many experts predict a near future where rescue robots will scour disaster zones en masse. But their success depends on the alignment of several disciplines.

First, a robot plunging into danger needs to power itself independently. These often very heavy devices require a lot of electrical power; the more power they have to carry on board, the heavier they are, which requires more power in turn, and so on. The solutions to this energy problem vary greatly. Boston Dynamics' BigDog carries a one-cylinder, two stroke Go-Kart engine (like those used in lawnmowers), which drives 16 hydraulic motors in its legs. By contrast, NASA's Opportunity rover can theoretically keep exploring Mars forever (provided the mechanisms still work) as it recharges itself with a solar panel.

In the world's foremost robotics competitions, entrants can't be tethered to external power or communications, and in the most rigorous tests, wireless communication is purposefully degraded to give them a chance to prove their self-help skills. While that seems tough, a city struck by a killer earthquake or a forest engulfed in flames will be a much greater challenge. Search and rescue bots will have to go deep into dangerous territory, cut off from human operators with patchy communication signals. It will be making its own decisions about what to do next, using machine learning and other AI algorithms to self-teach.

Pre-programming robots for unpredictable environments is incredibly difficult, but leaving a robot to its own devices would be dangerous. There's a sweet spot to be found, and 'learning to unlearn' certain behaviours can be just as important in the field. Restrict self-learning too much and the simplest obstacle might become a fatal stumbling block, like a flight of stairs or a door handle. Trust a system too much to try new things and it might decide a disaster victim is another piece of rubble and cause more harm.

The other secret to a successful search and rescue operation is sensors, and there are as many kinds as there are environments they have to work in. With feedback from accelerometers or gyroscopes in multiple dimensions, motion sensors give the robot critical information like orientation to the ground – an essential input when scrambling over wreckage. It can also get information about its movements from load-bearing sensors, which measure shifts in weight. The motors – known as actuators – then compensate, moving the body in the opposite direction to keep it upright. For robots that are connected to operators at a home base, visual sensors are crucial too. Cameras – often two of them to provide a sense of depth – can show the operator what's going on in the immediate area.

We can also design robots with sensors for dangers they're likely to encounter in specific environments. Sandia National Laboratories' Gemini-Scout is designed for mining accidents, finding and delivering provisions to survivors. As well as the ability to navigate rocky surfaces, debris, and even water and mud, it has a thermal imager to acquire video, a speaker and microphone for communication, and temperature and gas sensors so it can sense environmental hazards. Its devices are surrounded by explosion-proof casing, so if it's surrounded by explosive substances, the robot's electronics won't spark to trigger blasts.

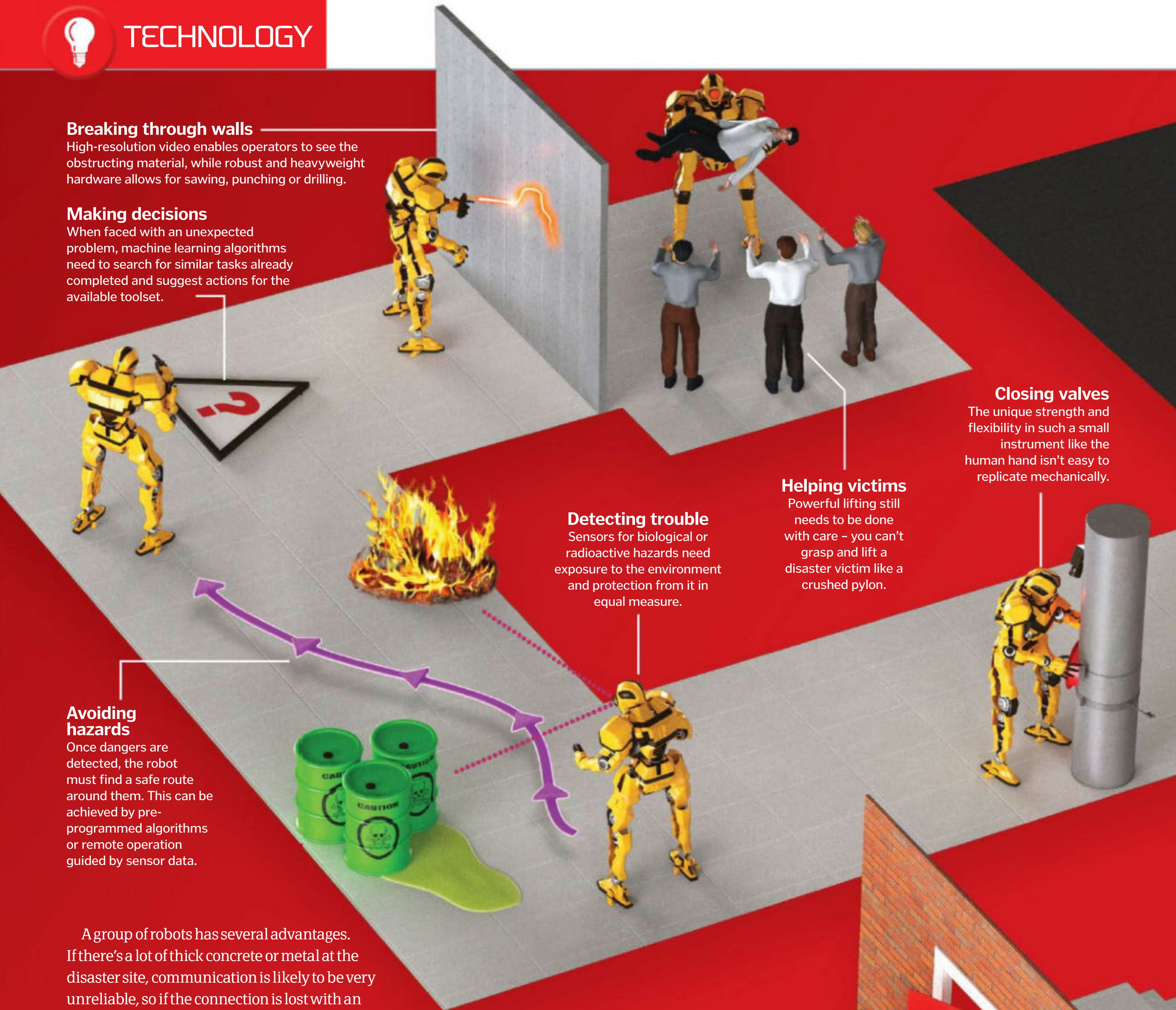
After the destruction caused by major disasters, getting from A to B to reach those in need can be difficult, demanding constant shifts in balance and weight that we humans do without thinking. Wheels are of limited use (although unique configurations of movable wheel arrays are catching on – see 'The Fukushima nuclear disaster' on page 23). Designs inspired by quadruped animals like Boston Dynamics' BigDog and Cheetah are also showing promise.

Although humanoid robots seem like a natural choice, the movements required for scrambling over wreckage are hugely complicated. Even standing upright is a demanding task for the robot's processor and motors, as they try to imitate a human's brain and muscles.

> *"Search and rescue bots will have to go deep into dangerous territory, cut off from human operators with patchy signals"*

Disaster robots got their first real debut when they were sent into the incredibly difficult terrain of the World Trade Center towers following the September 11 attacks. They didn't perform at all well, often getting stuck or breaking, but the test gave engineers a lot of real-world experience to work on the next generation of rescue bots.

However, after spending all that development time and money on a single machine only to have it crushed flat by a falling wall or run out of power at the worst possible moment and be lost forever, the answer might be to not put all your eggs in one basket. The solution for some environments might be an army of rescue robots, working as a team.



A group of robots has several advantages. If there's a lot of thick concrete or metal at the disaster site, communication is likely to be very unreliable, so if the connection is lost with an individual bot, it can be maintained along a chain between those that are still in range. The command will be passed down the line to the unit at the front line. A swarm also allows for a distributed processing model. Each unit has their piece of the puzzle but is also aware of the outlook of every other bot and can take over the decision-making or operator-response should something happen to its nearby fellows. It's a little like having one giant robot body and brain made up of small, fluid elements.

The members of a robot army don't need to be identical. Several different kinds of bot can be deployed, each with its own talents. Larger, longer-range robots could carry smaller and more specialised devices like snakebots deep into a disaster zone to go to work.

One snakebot model, designed by Japanese robotics professor Satoshi Tadokoro, is nearly eight metres long and propels itself using nylon bristles powered by tiny individual motors. It only moves at a crawl of five centimetres per second, but it can climb 20-degree inclines, turn sharp corners and see what's ahead with its front-mounted camera.

These low-powered snake-inspired robots are built for localised environments, but there's a way round this. Potentially, longer-range models could carry them to the burned out factory or collapsed building and deploy them to map and report back on the environment.

Whatever the shape or size, the search and rescue robots of the future will accompany and assist humans in dangerous conditions, or may even be able to go it alone, leaving their human operators in the safety of the control room.

PUTTING ROBOTS TO THE TEST

What obstacles will rescue robots have to overcome in a disaster zone?

Mapping a route
Stereoscopic vision and a robust memory can produce a picture of the environment, be aware of any dead ends, remember where the robot has been and help it get out again.

Moving heavy debris
Huge lifting power might have to be built into compact quarters, and systems like hydraulics are very energy intensive.

Tackling stairs
Just like on uneven ground, a small army of actuators and balancing sensors keep the robot upright as it climbs or descends.

Crossing uneven ground
Motors power movement to joints, while sensors constantly gauge orientation to the ground, in order to make constant, on-the-fly adjustments.

The Fukushima nuclear disaster

The area around Japan's Fukushima nuclear reactor was a no-go zone after the March 2011 tsunami led to equipment failure. The generators were unable to produce enough power to fuel coolant pumps, reactors ruptured and radioactive material poured out into the surrounding area and ocean.

Two Warrior robots, a gear-footed model from US robotics company iRobot, vacuumed radioactive dust into a tank attached to their arms, and were able to lift rubble weighing up to 90 kilograms. iRobot's Packbot, which has been used to defuse bombs in Iraq and Afghanistan, moved on innovative 'flipper' wheels and contained a complete hazmat kit to detect radiation, temperature and oxygen levels. A pair of Packbots moved through the ruined buildings, providing video and moving debris of up to 14 kilograms.

Another robot sent along to help in the aftermath was Quince, developed by Japan's Chiba Institute of Technology and Tohoku University. Quince features movable wheel arrays that let it climb and roll over uneven surfaces and up or down stairs. Controllable from over two kilometres away and waterproof, it collected samples and monitored radiation levels.

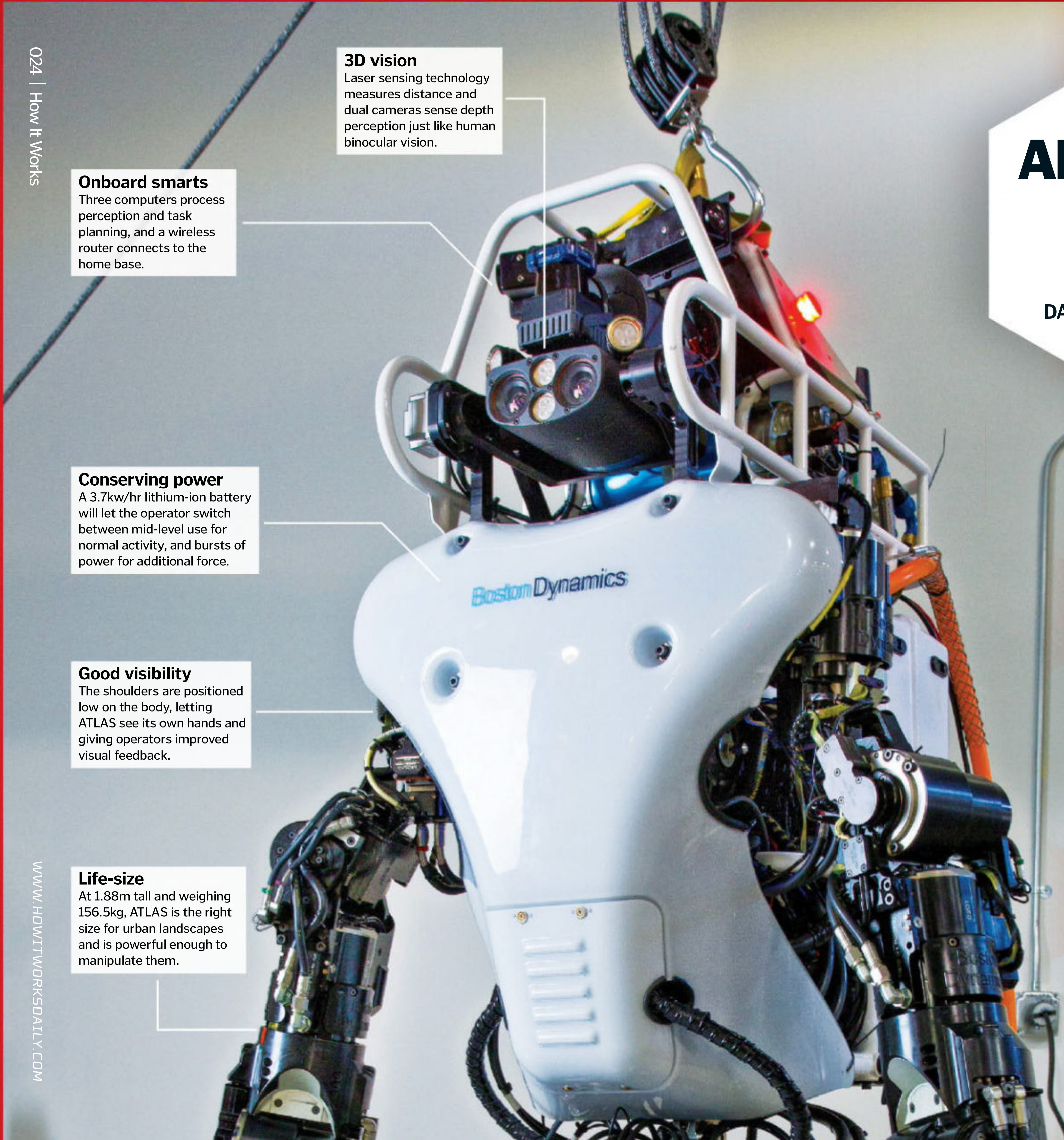
The Quince's unique wheel mounts let it both roll and step over uneven surfaces

Video footage of the radioactive Fukushima plant interior taken by Quince 2

Robots can grip objects or use tools to tackle hazards

ANATOMY OF A ROBOT

The tech behind DARPA's ATLAS disaster response bot



3D vision
Laser sensing technology measures distance and dual cameras sense depth perception just like human binocular vision.

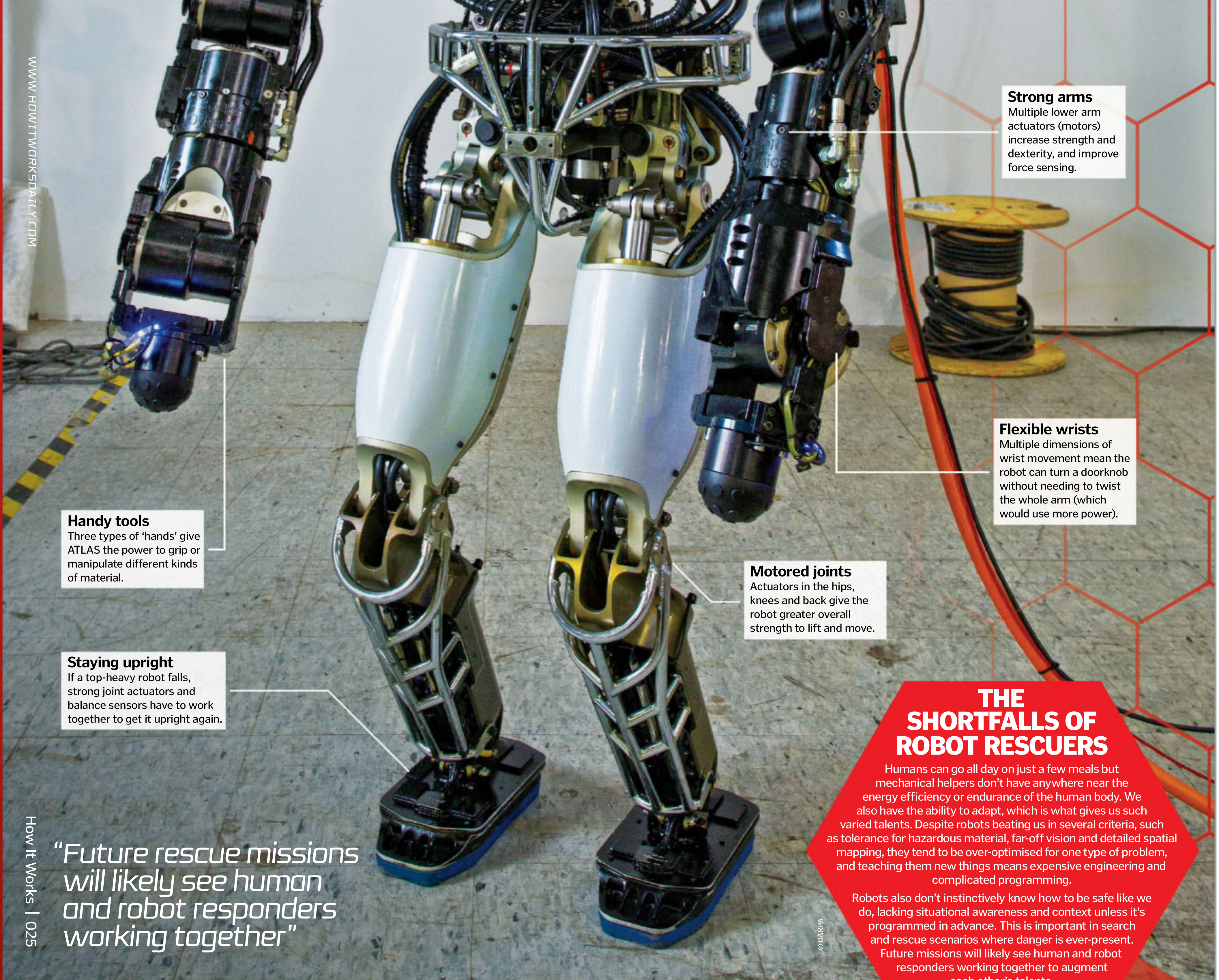
Onboard smarts
Three computers process perception and task planning, and a wireless router connects to the home base.

Conserving power
A 3.7kw/hr lithium-ion battery will let the operator switch between mid-level use for normal activity, and bursts of power for additional force.

Good visibility
The shoulders are positioned low on the body, letting ATLAS see its own hands and giving operators improved visual feedback.

Life-size
At 1.88m tall and weighing 156.5kg, ATLAS is the right size for urban landscapes and is powerful enough to manipulate them.

ATLAS was developed for DARPA by US robotics company Boston Dynamics



© DARPA

Strong arms
Multiple lower arm actuators (motors) increase strength and dexterity, and improve force sensing.

Flexible wrists
Multiple dimensions of wrist movement mean the robot can turn a doorknob without needing to twist the whole arm (which would use more power).

Motored joints
Actuators in the hips, knees and back give the robot greater overall strength to lift and move.

Handy tools
Three types of 'hands' give ATLAS the power to grip or manipulate different kinds of material.

Staying upright
If a top-heavy robot falls, strong joint actuators and balance sensors have to work together to get it upright again.

THE SHORTFALLS OF ROBOT RESCUERS

Humans can go all day on just a few meals but mechanical helpers don't have anywhere near the energy efficiency or endurance of the human body. We also have the ability to adapt, which is what gives us such varied talents. Despite robots beating us in several criteria, such as tolerance for hazardous material, far-off vision and detailed spatial mapping, they tend to be over-optimised for one type of problem, and teaching them new things means expensive engineering and complicated programming.

Robots also don't instinctively know how to be safe like we do, lacking situational awareness and context unless it's programmed in advance. This is important in search and rescue scenarios where danger is ever-present. Future missions will likely see human and robot responders working together to augment each other's talents.

"Future rescue missions will likely see human and robot responders working together"

How does a gas stove work?

Get the dinner on and find out how it cooks using gas

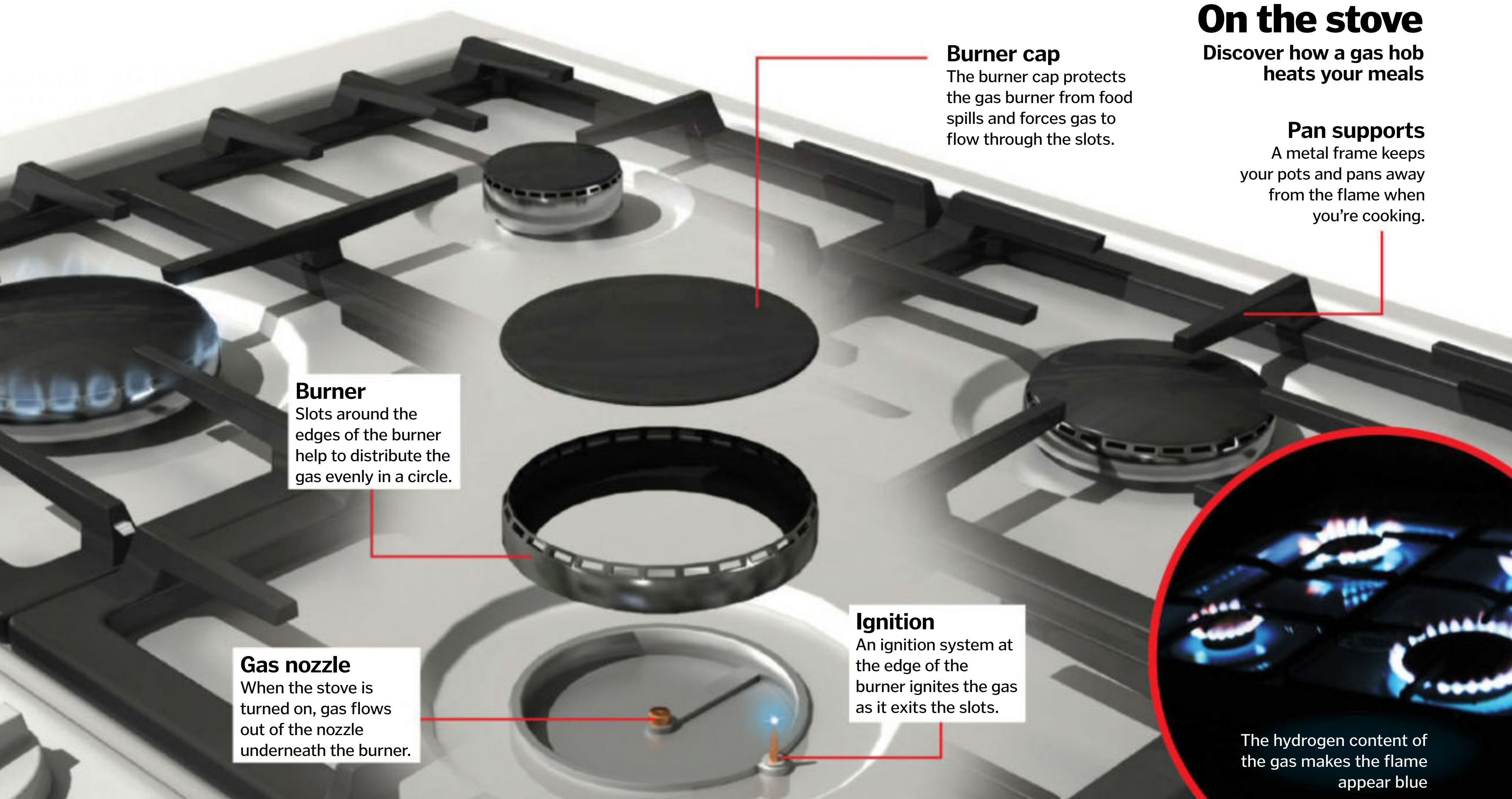
Gas stoves may seem like simple contraptions, but there is a lot of science going on behind the scenes. It begins with the natural gas or propane that flows through the main gas line to your house and is carried to a valve inside the stove.

When the stove is turned on, the valve opens, sending the gas through a Venturi tube, which narrows in the middle. When the gas enters the narrowed section, it flows quicker and the pressure drops, creating a vacuum. To fill this vacuum, air will then start rushing through an inlet in the pipe and combines with the gas to make it combustible.

This mixture of gas and oxygen is then released through the gas nozzle and ignited by either a pilot light or an electric ignition system. A pilot light is a burning blue flame fuelled by its own separate gas nozzle and is constantly on. An electric ignition system, on the other hand, is only activated when you press the ignition switch, and creates a spark that jumps to the burner and ignites the gas so you can start cooking.

On the stove

Discover how a gas hob heats your meals



The hydrogen content of the gas makes the flame appear blue

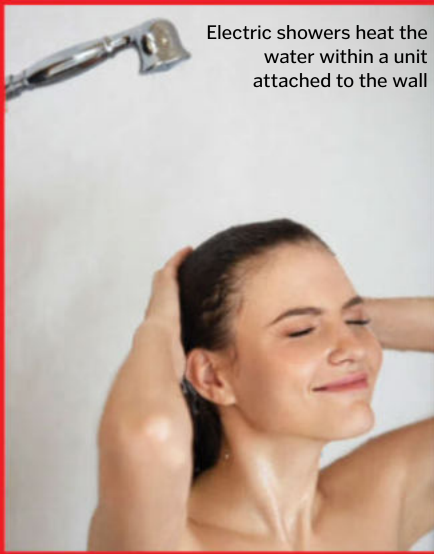
Electric showers

Discover what powers your morning shower and keeps the water hot

Electric showers work a bit like kettles, heating cold water quickly and on demand. This is particularly beneficial for busy households, as there will be no risk of a cold shower when everyone else has used all the hot water. Plus, it means they are environmentally friendly, as no energy is wasted heating water you won't use.

When you turn an electric shower on, a valve inside the unit opens and lets the cold water in. Some of the water flows into the heat exchanger, which contains a metal rod called a heating element that gets hot when an electric current is passed through it. As the water passes over the heating element, it warms almost instantly, and is then mixed with some cold water in a separate compartment until it reaches the desired temperature you have set.

The temperature you choose also controls the pressure of the water that comes flowing out of the showerhead. The higher the temperature, the more time the water will need to spend passing over the heating element, resulting in a less powerful stream.



Electric showers heat the water within a unit attached to the wall

Camera tech

Exposing the inner working of your digital camera

Compact system cameras are a cross between a compact and a DSLR

Digital cameras are incredibly complex gadgets, able to capture and process an image in just a fraction of a second.

There are three main types of digital camera. The most basic are compacts, which are usually pocketable, more budget-friendly and feature automatic modes, so all you need to do is point and shoot. However, the smaller size means a smaller sensor, which affects image quality. The reduced number of pixels means less information is recorded. To combat this, small sensors need to be more sensitive, which leads to grainy images.

Digital single-lens reflex (DSLR) cameras, on the other hand, are much bigger, so they can accommodate much larger sensors for crisp, clear images. They also enable you to change the lens, so you're not restricted to the focal lengths of a fixed-lens compact. Another big difference is the optical viewfinder, usually positioned on top of the camera. When framing shots with a compact camera, light enters the lens and travels straight to the sensor, which then displays a digital image on an electronic viewfinder, or LCD. In DSLRs, the light hits an angled mirror in front of the sensor, which bounces it up to an optical viewfinder. Then when you take the photo, the mirror flips up, letting the light pass through to the sensor so it can be recorded.

The third type of digital camera is the compact system camera, which is a cross between a compact and DSLR. These models don't have optical viewfinders, which is why they are also referred to as mirrorless cameras, but they do have an interchangeable lens. With larger sensors than most compacts, and more manual controls, they offer many of the advantages of a DSLR but in a smaller, lighter camera.

Controlling exposure

Photography is all about recording light. If your camera's sensor is exposed to too much light, your photo will be too bright, or overexposed, but if it is not exposed enough, it will be too dark, or underexposed. To control the amount of light that reaches the sensor, you can adjust the three main exposure settings. In auto mode, the camera will do this for you.

Aperture
There is an opening inside a lens called an aperture, the size of which can be tweaked. A large f-number (such as f22) makes the opening smaller, allowing less light into the lens, whereas a small f-number (such as f2.8) will widen it, allowing more light in. This also controls how much is in focus. Large numbers keep everything sharp, and small numbers will blur backgrounds.

f1.8; small f-numbers blur the background to make your subject stand out

f13; large f-numbers keep both the background and foreground in focus

Shutter speed
The time a camera's shutter stays open for can be adjusted with the shutter speed. A fast shutter speed (such as 1/250sec) will keep the shutter open for just a fraction of a second, only letting a bit of light in, whereas a slow shutter speed (such as 30sec) will keep it open longer. Fast speeds are great for sharp action shots, and slow speeds let you blur any movement in a scene.

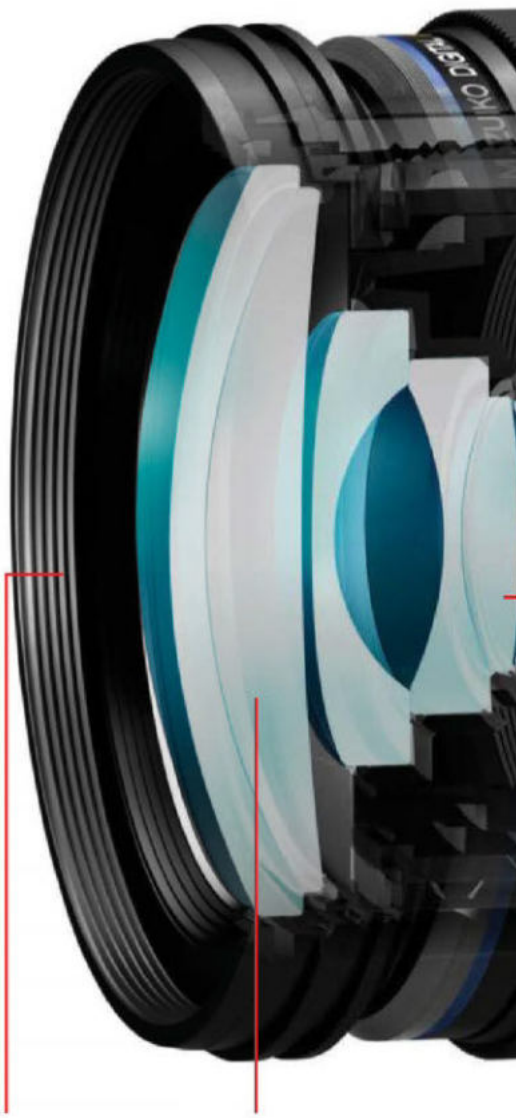
1sec; use a tripod when using slow shutter speeds to avoid blurring stationary subjects

1/1600sec; fast shutter speeds freeze any movement to capture a split second in time

ISO
By adjusting your camera's ISO setting, you can control how sensitive the sensor is to light. A high ISO (such as 1600) will boost the sensitivity, making the final photo brighter, but can also create digital noise, making your photo appear grainy. It's best to only increase the ISO as a last resort and adjust the aperture and shutter speed to brighten the shot instead if you can.

ISO 100; a low ISO will make sure you keep your photo crisp and clear

ISO 1600; a high ISO will brighten your shot but can make it grainy



Into the lens
Light bounces off the subject or scene you are shooting and enters the camera lens.

Focus the light
The curved glass of the lens bends all of the light rays onto one single point – the image sensor.

Stay focused

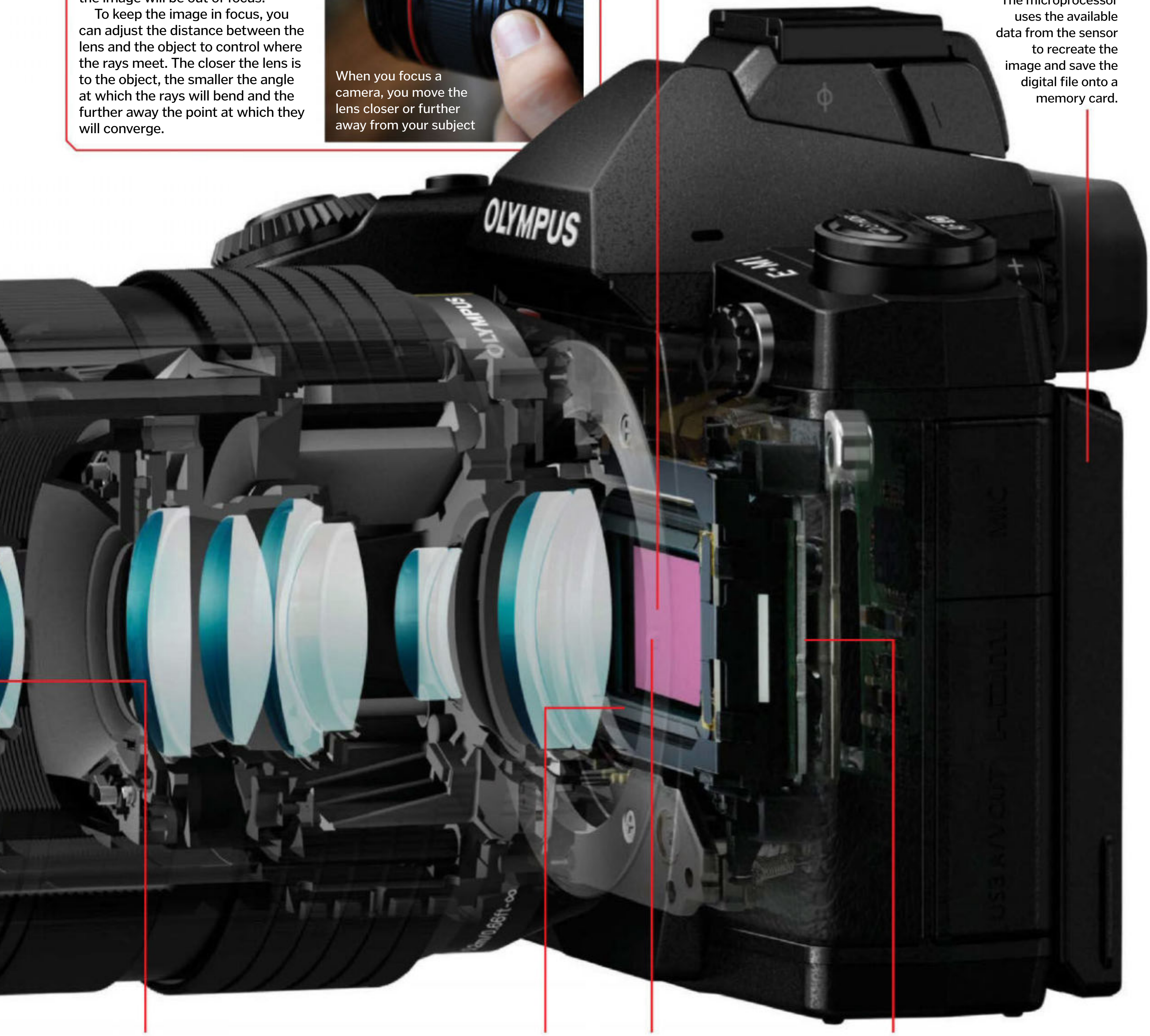
When rays of light bounce off of an object and pass through the lens, they bend at a certain angle and then converge on the sensor to create an image. If they converge too far in front of the sensor, or don't converge by the time they reach it, the image will be out of focus.

To keep the image in focus, you can adjust the distance between the lens and the object to control where the rays meet. The closer the lens is to the object, the smaller the angle at which the rays will bend and the further away the point at which they will converge.

When you focus a camera, you move the lens closer or further away from your subject

Picture perfect

What happens inside your camera when you take a photo?



Record the colour
In front of the sensor, a colour filter array ensures red, blue and green light only reaches certain pixels.

Making the final image
The microprocessor uses the available data from the sensor to recreate the image and save the digital file onto a memory card.

Accurate colours
The lens bends different wavelengths of light at different angles, so a further series of lenses helps to realign the colours.

Capture the light
A mechanical shutter in front of the sensor opens briefly, letting light through. The time that it remains open for is known as the shutter speed.

To the sensor
The sensor is made up of millions of light sensitive cells called pixels, which convert the light into electric signals.

Process the data
The electrical charge of each pixel provides the camera's microprocessor with information about the colour and brightness of the light.

How to locate underwater oil

The tech that can scan the seabed for one of Earth's most valuable resources

Oil – the world's most important fuel – is formed from prehistoric plants and animals that lived in the ocean millions of years ago. The resources are finite so geologists are constantly on the hunt for fresh supplies.

One of the most common methods is seismic reflection – creating shock waves that travel through the Earth's layers and examining waves that are reflected back.

A survey ship fires pulses of compressed air and these sound waves (which are similar to those produced by earthquakes) travel down the water and penetrate the rock layers. The time it takes for the waves to reflect back depends on the type or density of rock it encounters.

A set of pressure sensitive devices called hydrophones are used to detect bundles of these reflected sound waves. These are converted into images that seismologists use to interpret the structure below the surface, similar to how doctors use X-rays to see inside a body. If a potential location is found, the coordinates are plotted and the spot is marked with a buoy.

Seismic imaging

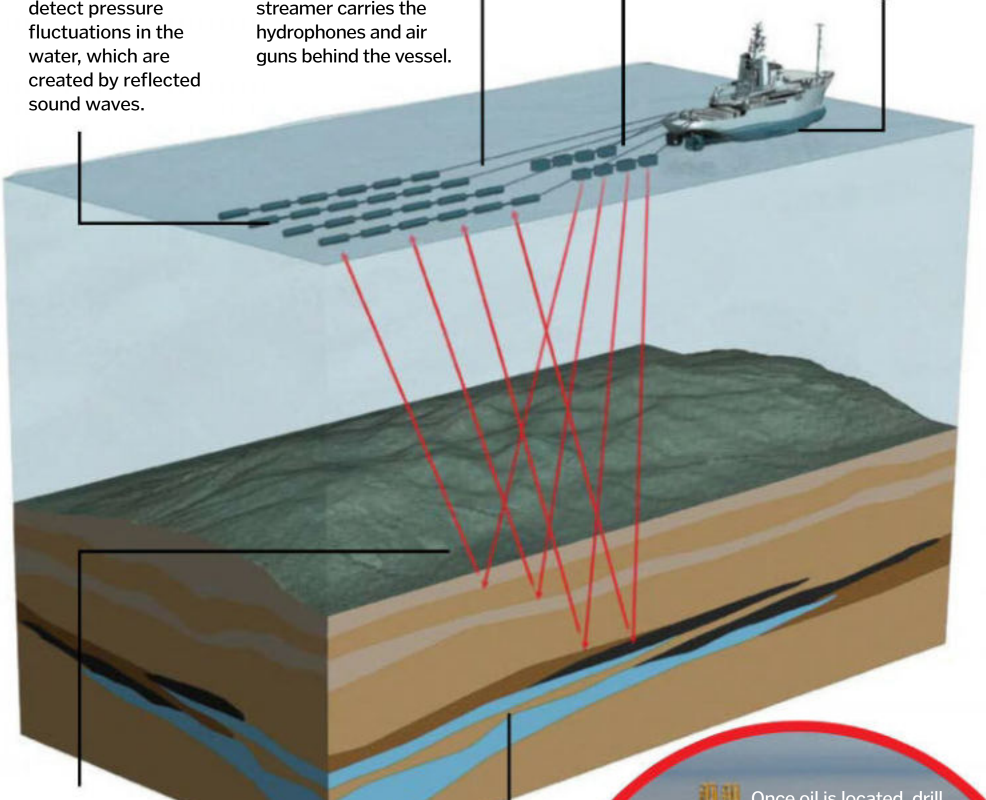
Learn how hydrophones can detect the presence of oil

Hydrophones
These underwater microphones can detect pressure fluctuations in the water, which are created by reflected sound waves.

The streamer
Measuring up to 12 kilometres in length, the streamer carries the hydrophones and air guns behind the vessel.

Air guns
Sound waves travel down to the seabed and penetrate the various layers of rock and sediment.

Computer processing
Specialist computer software is used to compile the hydrophone readings and produce a cross-section of the underwater rock.



Reflected waves
Underwater objects reflect sound waves differently, which helps scientists to identify potential oil locations for drilling.

Seismic velocity
This is the speed at which sound travels through a particular object.

Once oil is located, drill ships dig beneath the seabed to access it

Photoelectric cells explained

How do automatic doors and taps know you're there?

There's no magic involved in these everyday gadgets that can sense your presence. Both work with the help of photoelectric cells, which use light's photons (its elementary particles) to generate electricity.

One type of this cell contains 'photoconductive' materials, which means their ability to conduct electricity changes when they are subjected to light. Each cell features a small lens that is fitted over a piece of light-sensitive calcium sulphide. When light shines through the lens, the electrons become more mobile, which reduces the overall resistance in the cell. This allows current to flow through the circuit freely.

Some automatic doors and taps work using light-dependent resistors (LDRs) – a type of photoconductive cell. A beam of infrared light is shone in front of the door or tap and received by an LDR, enabling a steady flow of current to pass through it. When something blocks the beam of infrared, such as a person, it can no longer be detected by the LDR. This causes an increase in the cell's electrical resistance and a reduction in the flow of current. A separate circuit detects this change and triggers the door to open or the tap to switch on. A few seconds after the beam of light is restored, both will reset to their default closed position in response.

As soon as the sensor beam is disrupted, the tap turns on

Disney Infinity

Step into your favourite Disney worlds with this gaming gizmo

Ever since Woody and Buzz first appeared on the big screen, the idea that toys come alive when humans aren't around has fuelled many an imagination. Now Disney is making *Toy Story* a reality, with a videogame that transports your physical toys into a virtual world that you can control and explore.

Disney Infinity uses a docking station called the Infinity Base to bring Disney character figurines to life on your console or PC. It's all down to Radio Frequency Identification (RFID) tags – smart barcodes that use electromagnetic fields to pass on information. Each figurine contains one of these RFID tags, which stores data about which character it is and which level it is currently on in the game.

When a figure is within range of the Infinity Base, an RFID reader receives its encoded information and communicates it to the game, causing the character to appear on the screen. You can then collect more and more characters and join them on their adventures in a variety of Disney-themed worlds.

Disney Infinity isn't the only game to make use of this technology though, as *Skylanders* and *LEGO Dimensions* also combine physical figurines with on-screen gameplay to bring your toys to life.

What is RFID?

Radio Frequency Identification has been around since the 1970s and is a more primitive version of the Near Field Communication (NFC) used by many smartphones. While NFC enables two-way communication between devices, RFID can only pass data from a tag to a reader, making it much simpler and cheaper.

RFID tags can be passive or active, depending on how they are powered. Active tags contain a small battery that allows them to transmit their signal regularly, but passive tags are powered by the electromagnetic field generated by the reader.

From tracking animals and luggage to enabling contactless payment, one of the biggest benefits of RFID tags over traditional barcodes is that they don't need to be visible. In the future, they could replace barcodes altogether, enabling shops to scan all of the items in your basket at once, to reduce queuing times.

Some contactless payment cards use RFID technology to send information wirelessly to the card reader

Inside the magic

How your toys are transported into videogames

Sending information
The tag's antenna sends information about the toy stored on the microchip to the reader via radio waves.

Tag
The base of the toy contains an RFID tag, featuring a microchip and an antenna.

Reader
An RFID reader in the Infinity Base sends out electromagnetic waves that the tag's antenna is specially tuned to receive.

Wireless power
The electromagnetic field generated by the reader's antenna powers the microchip in the tag, just like a wireless charger.

Powering the base
The Infinity Base plugs into your console via USB and receives its power through the cable.

Message received
The reader picks up the tag's radio waves and a microchip converts them into digital information that it sends to your console.

Amazon: from click to delivery

Run by computer algorithms, the online retailer's warehouses are a hive of activity

Amazon sells around five billion items every year and its enormous warehouses – dubbed 'fulfilment centres' – are at the heart of the operation. These are much more than colossal, shelf-packed spaces; they are networked, algorithm-run engines working to satisfy the needs of Amazon's 270 million customers.

When an online purchase is made, the Amazon computer system instantly assigns a warehouse to process the order. The location of the item is quickly identified, and a human 'picker' receives a notification on their handheld scanner telling them to fetch it. Employees carry these devices at all times, which also work to direct them to the item they need to source. The scanners also ensure targets are met by displaying a countdown, which shows the workers the time they have to retrieve the product.

The items are not arranged in categories as you might imagine. Instead, they are stored almost at random throughout the hundreds of shelves. This actually helps the staff, as trying to pick an item from a group of a thousand similar alternatives would slow them down considerably. Once the item has been picked and scanned, it travels along a complex system of conveyor belts to a packing station. Here, the products are packaged into cardboard boxes, ready to be collected by delivery trucks.

At the moment, humans are still an integral part of the overall process, but that could change in the future. Amazon Robotics, a subsidiary company, is developing robots that bring items to the picker. These robots, called Kiva, can locate the items and carry the entire shelf to the staff, who would lift the item off and package it. This idea is currently being trialled in some of Amazon's warehouses in the US, and could be seen throughout its many fulfilment centres in the coming years.

"A countdown shows the workers the time they have to retrieve the product"

Drone delivery

In November 2015, Amazon unveiled its latest 'Prime Air' prototype, part of a revolutionary drone delivery service that it plans to launch in the coming years. Weighing less than 25 kilograms, Prime Air vehicles will take off from Amazon's warehouses like helicopters, rising vertically to roughly 120 metres.

Amazon's latest design converts to a streamlined, high-speed airplane once it has reached the appropriate altitude, and flies direct to its destination, up to 24 kilometres away. This prototype uses a lightweight lithium-ion battery to power its nine propellors – eight of them provide vertical lift while a larger propeller at the rear drives the drone forward.

During its journey, the drone will use 'sense and avoid' technology to identify potential hazards. When it arrives at its destination, it reverts to vertical mode, lowering itself to the ground and dropping off the parcel before flying back to base.

This is just one of a dozen drone prototypes that Amazon has designed

© REX

How the Roomba vacuum cleans your house

Discover the robot that takes the hard work out of housework

An entire army of cleaning robots is ready to start invading your home, including the iRobot Roomba vacuum cleaner. This little machine uses a suite of sensors to navigate around your home on its own, sucking up dust and dirt along the way.

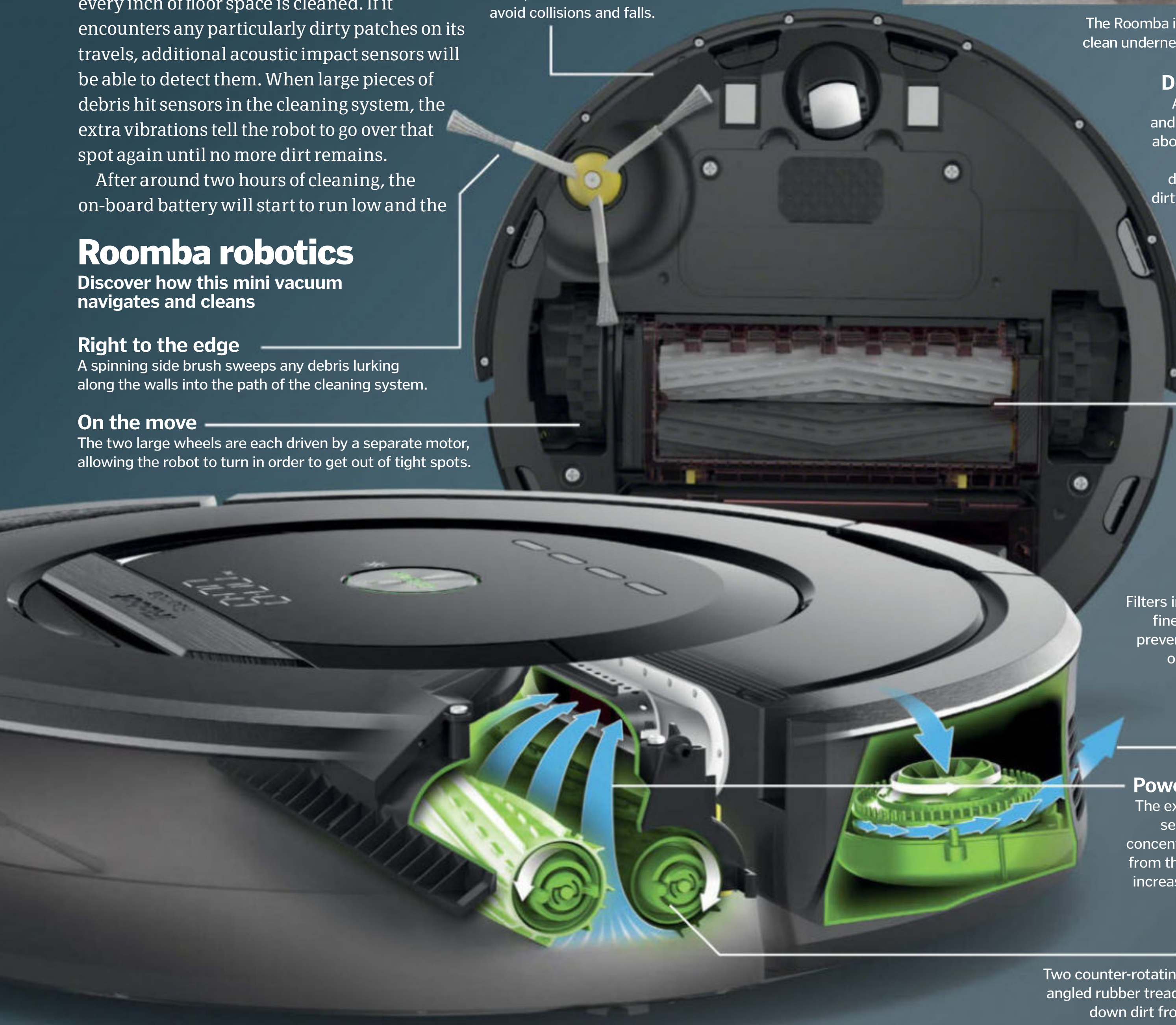
By sending out beams of infrared light and measuring how long it takes for them to bounce back, the Roomba can work out the location of walls and obstacles in its path. It will then plot a systematic route around the room to ensure every inch of floor space is cleaned. If it encounters any particularly dirty patches on its travels, additional acoustic impact sensors will be able to detect them. When large pieces of debris hit sensors in the cleaning system, the extra vibrations tell the robot to go over that spot again until no more dirt remains.

After around two hours of cleaning, the on-board battery will start to run low and the Roomba will use further infrared signals to find and return to its charging station. Then, when you want it to spring into cleaning action again, you just need to press the start button on top, or schedule the next cleaning session via an app downloaded to your mobile device. That way, you can start the housework before you've even got home!

The Roomba is small enough to clean underneath your furniture

Roomba robotics

Discover how this mini vacuum navigates and cleans



DISCOVER HOW MAN AND MACHINE CONQUER THE DEADLIEST ROADS ON EARTH

EXTREME TRUCKERS

"The ice roads are not actually roads at all"

Risking your life to transport cargo over snow and ice is not a career to suit everyone, but for the ice road truckers it's a challenge that they relish year after year. Every winter they journey to northern Canada and Alaska, hauling heavy loads to some of the most remote places on Earth. This may not seem all that dangerous, but it becomes a lot more terrifying when you learn that the ice roads they're driving on are not actually roads at all.

When temperatures plummet to -40 degrees Celsius or below, rivers, lakes and even stretches of ocean freeze over, creating passages to businesses and communities that have been isolated for the rest of the year. During this short ice road season, the truckers race along these routes to deliver much-needed supplies before their window of opportunity closes, but a tight schedule is the least of their worries.

With the lake ice sometimes only one metre thick, driving a 45-kilogram rig to the other side is a scary business. Going too fast or too slow will cause the ice to crack and break, plunging the truck and driver into the freezing waters below. When they eventually reach firm ground, icy hills and bends in the road create a further challenge, as the drivers struggle to maintain control of their vehicles on the slippery surface. This is even more of a problem in a whiteout, when heavy snowfall or fog creates a lack of contrast in the snowy landscape, leaving the driver unable to see the road up ahead.

Overturned trucks are a common sight on the banks of the ice roads, but even if the driver survives the initial accident, they are then left to fight for their life in unforgiving conditions. Outside the warmth of their cab, hypothermia and frostbite can quickly set in, and with civilisation often hundreds of miles away, they only have the ferocious wolves and polar bears for company.

With all of these potential dangers in the back of their mind, the truckers also have to deal with incredibly long hours on the road, often going without any human contact for days on end. Yet, while it's certainly a gruelling, lonely and terrifying job, the call of the ice roads keeps them coming back for this annual adventure.

Deadliest routes

Ingraham Trail
Across the cracking ice lakes, truckers transport heavy loads to and from diamond mines between Yellowknife and the Tibbitt Lake in Canada.

Dalton Highway
Tackling several steep icy hills along the way, truckers travel 650 kilometres across Alaska to the oil fields on the northern coast.

Dempster Highway
By crossing rivers, lakes and even the Arctic Circle, much needed supplies can be delivered to Canada's remote northernmost settlements.

Manitoba winter roads
Navigating the treacherous ice roads, truckers travel across Canada's Manitoba province to resupply communities isolated for ten months of the year.

Why don't they just fly?

Your ice-trucking questions answered

Q How much can you earn?
A trucker can earn between £13,500 ($20,000) and £54,000 ($80,000) in a season. That's the equivalent of earning a regular trucker's salary in just a couple of months, so they are well rewarded for their hard work.

Q What type of freight is hauled?
The rigs can carry anything from household appliances and furniture, to building materials and sometimes even entire buildings. They also regularly transport oil from the oil fields near the Arctic Circle.

Q Why not wait until summer?
In summer the ice roads simply don't exist, as the frozen lakes and rivers that the truckers drive across have thawed. This leaves many communities only accessible by boats, which cannot carry such weighty cargo as the trucks.

Q How long is the ice road season?
The season usually begins in mid-January and lasts until mid-March, but the temperamental climate can sometimes cause the ice to begin to melt after just six weeks, providing the truckers with a very short delivery window.

Q Why don't they just fly the cargo instead?
Although transporting the cargo by plane would be easier, most of the loads the truckers haul are too big and heavy to fly. There are usually no airports near to the delivery point either, and if there were, the regular snowstorms would make it very difficult to land.

Loaded trucks have a high centre of gravity, increasing the risk of rollovers

Life on the ice roads is extremely isolated

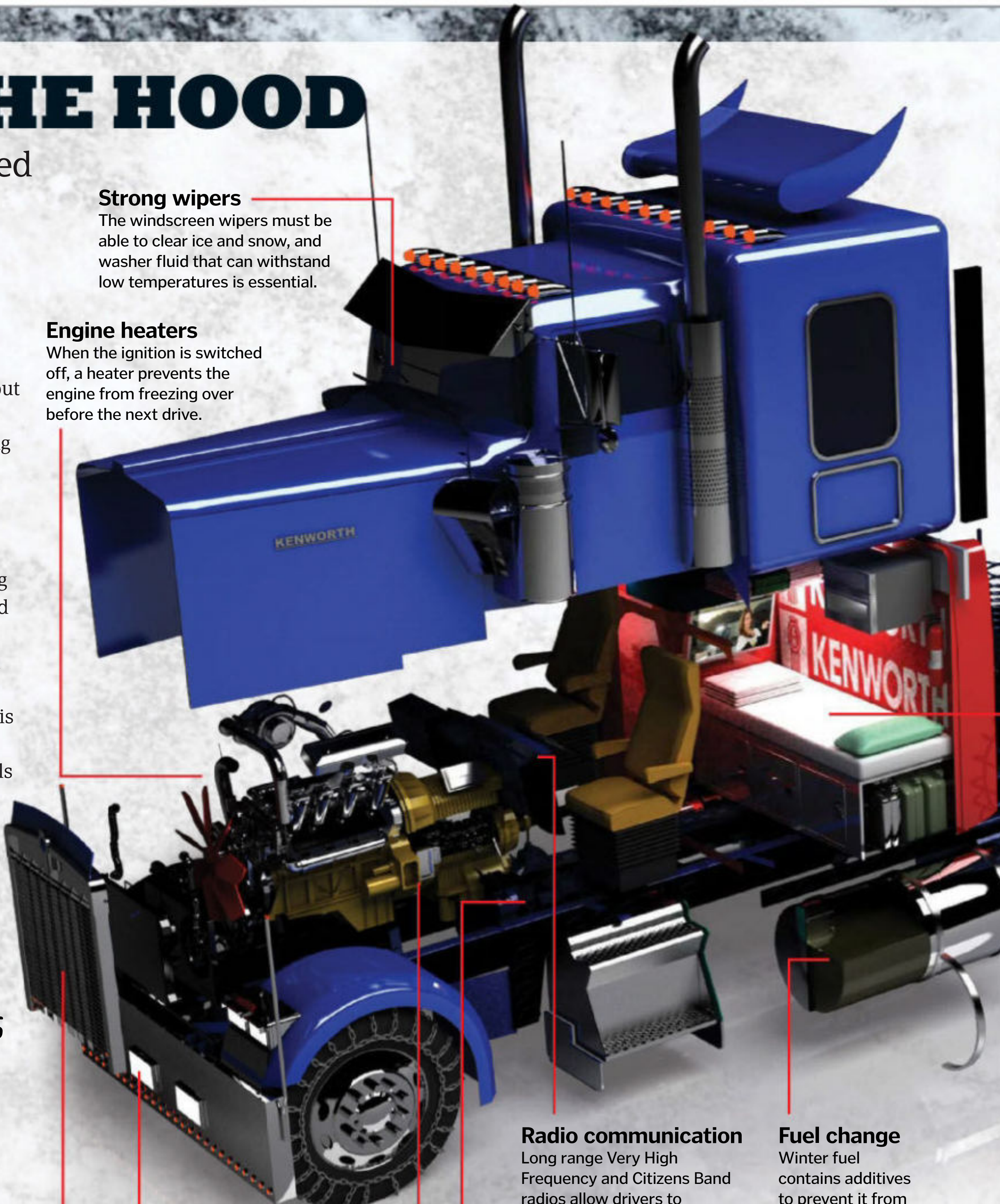
UNDER THE HOOD

How ice road trucks are kitted out for the long haul

Out in the extreme cold, a regular highway truck wouldn't survive for long. When temperatures reach as low as -50 degrees Celsius, even steel becomes brittle and breakable, and fuel can freeze instantly. To make sure a truck remains in action throughout the ice road season, companies must spend many hours and around £6,800 ($10,000) fitting the vehicle with special components that can withstand these incredibly harsh conditions.

The rigs typically used on the ice roads are heavy-duty Class 8 trucks, also known as 18-wheelers, as they are capable of hauling big loads. The driver sits behind the turbocharged diesel engine, which, in addition to the reinforced chassis, gives the semi-articulated truck its immense pulling power.

When setting off on the ice roads, the truck is well stocked with everything the driver will need for their journey, including plenty of tools and spare parts. If a truck breaks down, help is often several hours, if not days, away, so it's usually up to the driver to carry out the repairs themselves. Therefore a good knowledge of truck mechanics is essential, as well as first aid training for if any accidents happen.



Strong wipers
The windscreen wipers must be able to clear ice and snow, and washer fluid that can withstand low temperatures is essential.

Engine heaters
When the ignition is switched off, a heater prevents the engine from freezing over before the next drive.

"Trucking companies spend many hours and around $10,000 outfitting their rigs"

Radiator cover
A cover over the grille helps to keep moisture away from the engine that could rapidly freeze.

Headlights
Extra upward and downward facing lights are installed to give the driver a better view of upcoming hills and ditches.

Air dryer
It's important for the truck's air supply to be clean and dry, as any moisture will quickly freeze and cause damage.

Seal the gaps
Any openings around the pedals and steering column are sealed to prevent moisture from getting in and freezing.

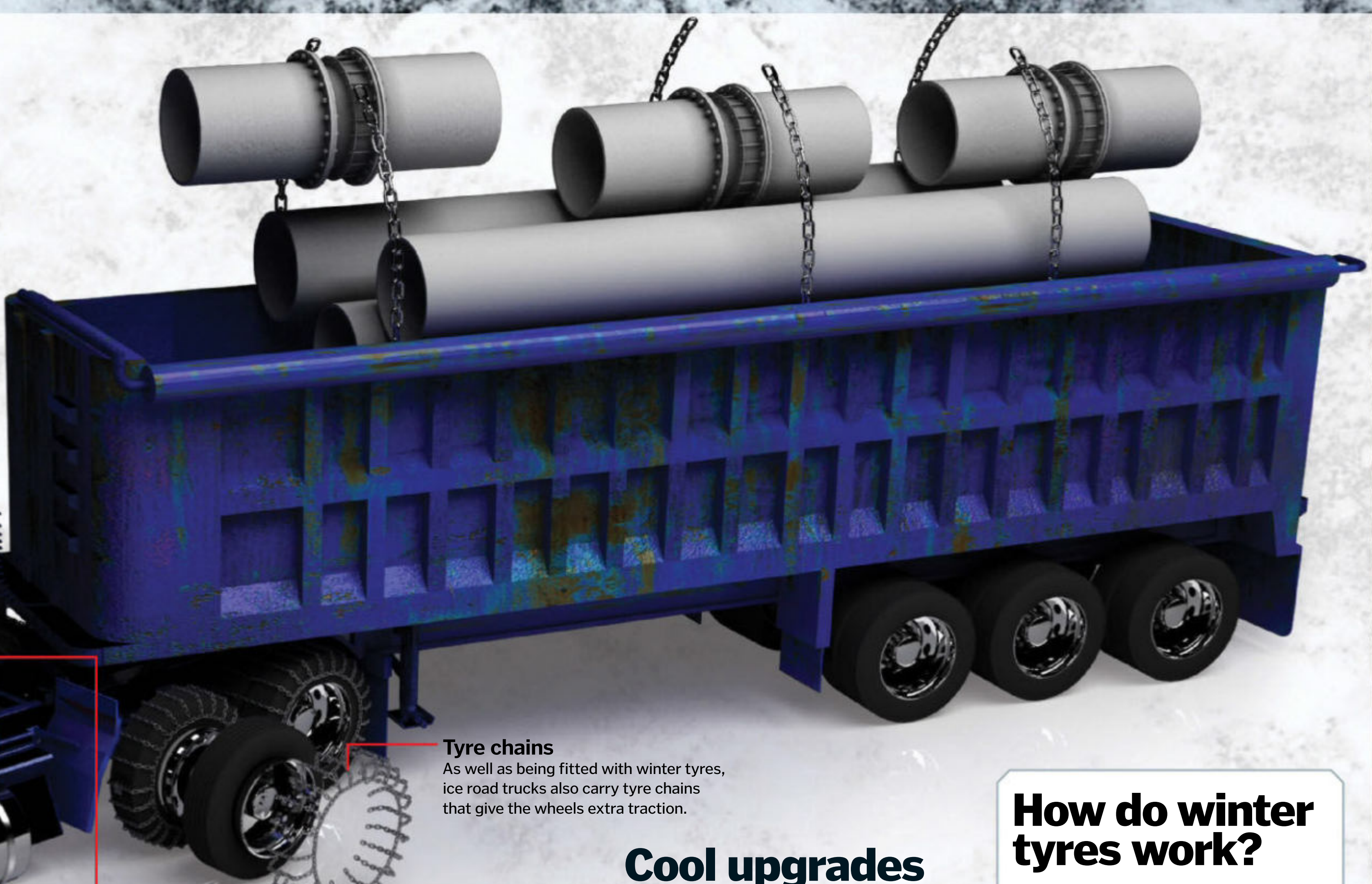
Radio communication
Long range Very High Frequency and Citizens Band radios allow drivers to communicate with each other and the emergency services.

Fuel change
Winter fuel contains additives to prevent it from gelling, and synthetic oil is used to prevent engine lubricant from thickening.

In the cab

On the long, remote ice roads, truckers remain in their cabs for days or even weeks at a time, so it's important that their home away from home is comfortable. Heaters and insulation ensure the cab remains warm even when it's subzero outside, but warm winter clothing is also a must for when the driver needs to get out and fix the truck. They also need to remember to pack their sunglasses, as UV light reflected off of the snow can cause niphablepsia, or snow blindness. A bed behind the driver's seat enables them to get some much-needed rest, and a refrigerator of food and drink supplies keeps them fuelled up for the journey ahead. With no phone signal, a satellite phone enables them to keep in touch with their loved ones and call for help if needed, and a Personal Locator Beacon can be used to guide rescue agencies to their location.

Truckers often have an entertainment system for watching DVDs in their downtime



Tyre chains
As well as being fitted with winter tyres, ice road trucks also carry tyre chains that give the wheels extra traction.

LED lighting
All light bulbs are changed for LED lights, as they can better withstand the vibrations on the ice roads.

Cool upgrades

The modifications needed for driving in sub-zero temperatures

How do winter tyres work?

Winter tyres contain a higher percentage of natural rubber than their regular counterparts, and are made from a softer compound. This prevents them from becoming rigid in freezing temperatures, so they can bend and maintain more contact with the ice for better traction. The surface of the tyre is also covered with lots of tiny slits called 'sipes'. These help to clear water and snow from the treads of the tyre, so they do not become compacted and slippery. They also help to bite into the snow to improve the tyre's grip on low friction surfaces.

Before ice road season, the truck's tyres are swapped for winter ones

REAL-LIFE EXPERIENCES

Growing up with the smell of diesel and grease, Vlad Pleskot started driving tractors and trucks at the age of ten on his family's farm. He now has over 20 years of trucking experience and is the owner of successful trucking company VP Express Inc in Canada. Every year, Vlad risks his life on the ice roads, and has shared some of his terrifying trucking stories with us.

What does a typical day of ice road trucking consist of?
You wake up very early after just a few hours of sleep, make your coffee and breakfast and put your truck into gear. Then you drive all day, very slowly, trying to stay on the road, trying not to break anything on your truck or load and trying not to get stuck in the snow or go through the ice. You must remember the reason why you do all of this; why you left your family behind for months at a time, why you signed up for one of the most dangerous job on Earth. The people up north are depending on you for their very existence.

What qualities do you need to be good at the job?
Despite the belief that to be a good ice road trucker you need to have vast experience with hauling various loads, I would say that the most important thing is the willingness to do a job that not many others can do, plus extraordinary problem solving skills.

What has been your scariest moment?
Almost every single trip you experience a moment that makes you think, 'why the hell am I here?' I went through the ice, I lost my wheels, my truck broke down in -45 degrees Celsius weather and I had to survive with no heat. But the scariest moment was when I got stuck in mud at the end of the season when the road was closed and I was the last one to go out. I couldn't get help and so I had to leave my truck behind and walk for days through the forests to get back to civilisation.

What are the best and worst things about the job?
The best thing is the adrenaline rush you experience every trip. It's the same reason why people do extreme sports. That feeling that you might die any moment, the feeling that not many other people can do this job. The worst feeling is that your family worries about you and the hopelessness you feel when something happens at home and you cannot get there. Plus, any trivial mistake can land you in hospital, or a morgue.

Winter driving tech

The safety features that stop you from spinning out

While you probably won't ever have to navigate the remote ice roads of Alaska in a 20-ton truck, you may still find yourself having to confront an icy commute in your hatchback. Maintaining control of your vehicle in these conditions is notoriously difficult, which is why driving on snow and ice causes thousands of fatalities every year.

Most modern cars have built-in technology that can help prevent such catastrophic accidents, such as Electronic Stability Control (ESC). This system uses a sensor to constantly monitor the driver's steering input and the direction in which the car is pointed. If the car starts to skid, ESC detects that it is not heading in the intended direction. The central computer then takes control to slow the vehicle down and activates the brakes on individual wheels in order to straighten it up again.

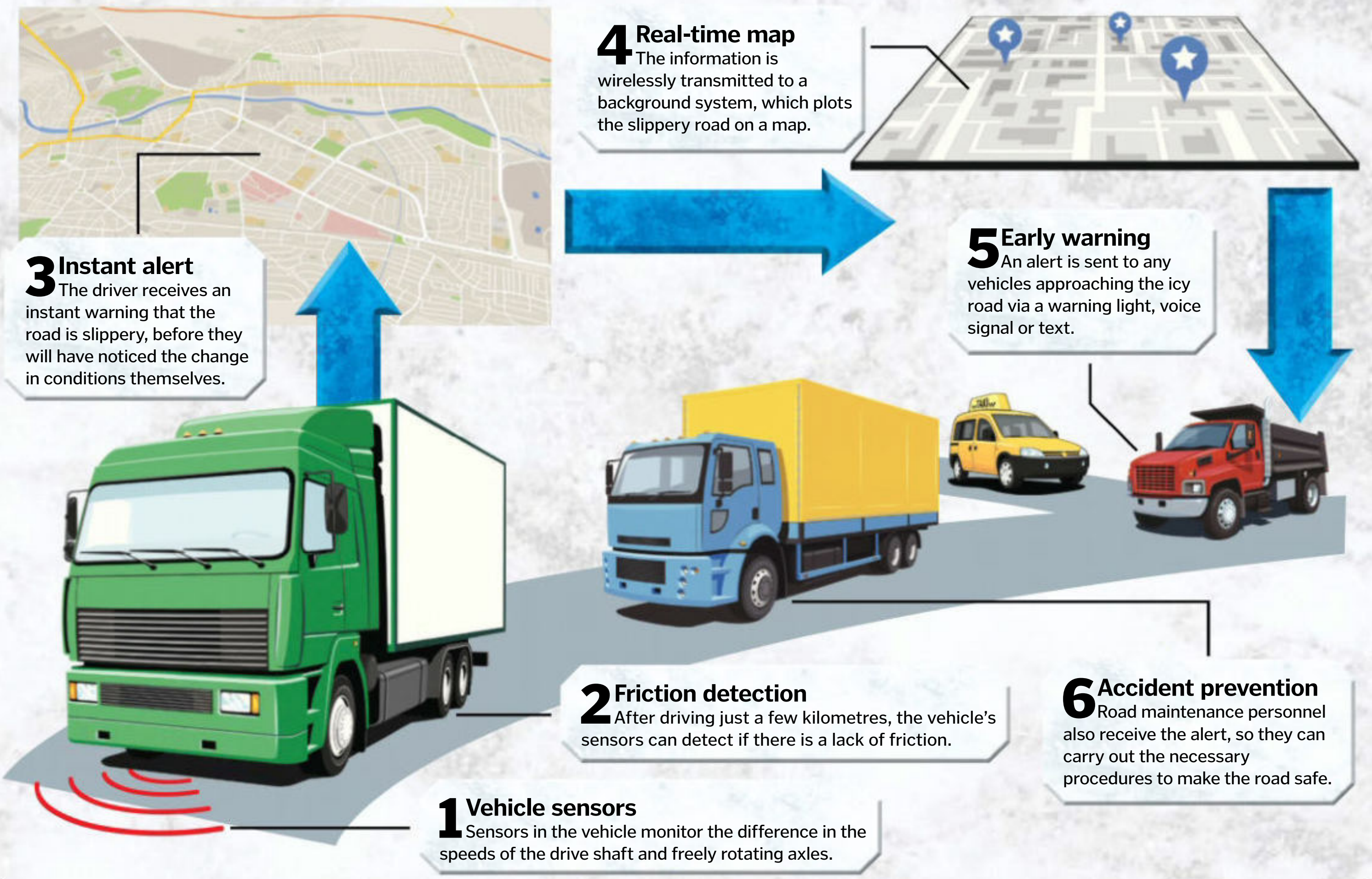
To do this it uses an anti-lock braking system (ABS). When trying to slow your car down in ice, the brakes can lock and cause the car to skid. ABS uses speed sensors on each wheel to detect if they quickly decelerate, a sign that they are about to lock, and then rapidly pulses the brakes to prevent that from happening. This enables you to maintain grip on the road and steer your car to safety.

These systems are already widely used, but many other safety breakthroughs are still in development. For example, Finland's VTT Technical Research Centre has been working on an automatic slipperiness detection system that can warn drivers if they are approaching icy roads, pictured on the page opposite.

Skidding is a major risk for trucks, as their trailers can swing out behind them

Slipperiness detection

How VTT's innovative system warns drivers of ice up ahead



DRIVING SAFELY ON SNOW AND ICE

When the road gets icy, a lack of friction between it and your tyres can make your car difficult to control. Friction is normally what keeps your wheels gripped onto the road, so without it they will slip and slide around, making it very difficult to steer or brake. To reduce the risk of an accident, make sure you drive slowly and cautiously if there is a chance of ice, and leave plenty of room between your car and the vehicle in front. If you do lose control, you will need to regain control of your motor as quickly as possible, so it's very useful to know what to do in the event of a skid.

How to stop a skid

Be prepared for when you lose control on the ice

1 Slow down
Take your foot off the accelerator but do not hit the brakes, as this will cause the wheels to lock and skid further.

2 Steer into it
Gently turn the steering wheel in the direction that the rear of your car is sliding to put it back on the correct course.

3 Get to safety
Once the car has stopped skidding, steer it towards a surface with more traction, such as a patch of snow on the side of the road.

The physics of countersteering

Why motorcyclists must steer in the opposite direction to turn corners

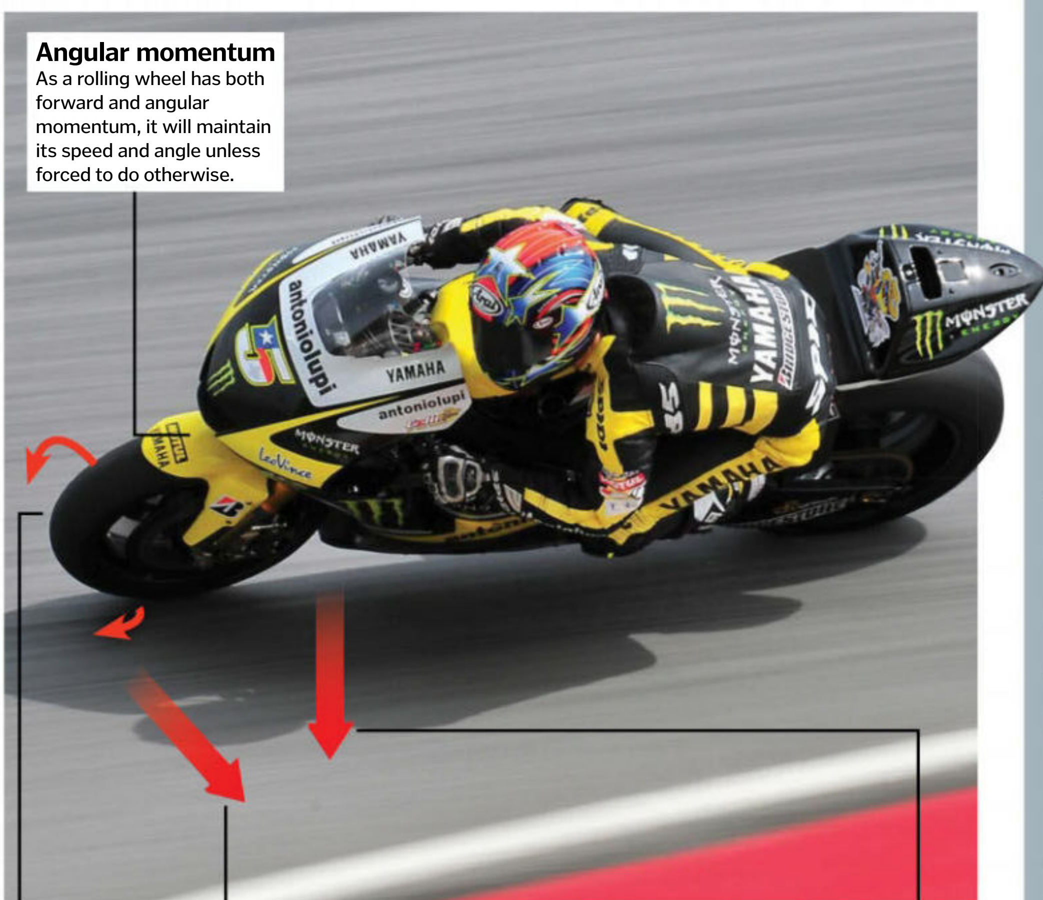
When taking a corner, a motorcyclist will momentarily steer in the opposite direction to where they want to go. This is known as countersteering, and is a safer way of turning at high speeds.

To turn left, you start by pushing gently on the left-hand grip, which turns the front wheel to the right. This positions the wheels for a right-hand turn – the opposite way you want to go – but as you are going from a straight direction of travel, this turn is unstable. The friction created between the wheels and the ground, known as centripetal force, causes the bike to tilt the other way. This leans you and the bike to the left, setting it up for a left turn instead.

Once you've released the pressure on the left-hand grip, the bike will perform a safe, stable, left-hand turn. The amount you lean is also very important – lean too much and the bike will fall, lean too little and the centripetal force will overcome gravity and throw you out of the turn. Taking a turn incorrectly can lead to severe injury.

Mastering the turn

How do riders balance out forces to keep their bike from falling?



Real-time traffic data

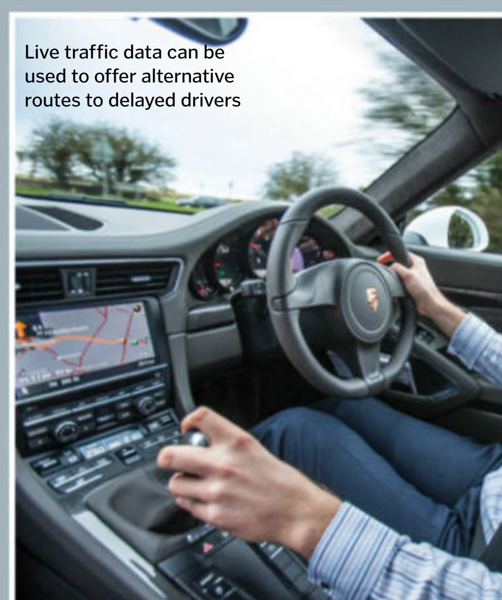
How modern sat navs keep you up to date with the latest traffic news

When sat navs first came onto the market they functioned only to get you from one place to another. Modern varieties now offer live traffic data, to keep you aware of developments on the roads as they happen in real time.

The bulk of this information is actually provided by the drivers' journeys as they're undertaken. A small mobile device, similar to a SIM card, is built into the sat nav, which sends data on the speed it's travelling at and its precise geographical location back to the manufacturer's headquarters.

Along with this data, live information is gathered from mobile phone networks, radio reports and government organisations, which have access to traffic data through a multitude of cameras and road sensors. These detect the volume and speed of vehicles, using either radar or active infrared, and then wirelessly transmit the results to a server. By combining these various data sources, it's possible to show where the most congestion is and where traffic is flowing freely.

Live traffic data can also be used to create faster, alternative routes for drivers who are already part way through their journey. Once these have been compiled they are sent directly to sat nav systems; drivers can then choose to change their route to save some time or continue on their original path.


Live traffic data can be used to offer alternative routes to delayed drivers

Supersonic aircraft

Fly faster than the speed of sound from 2021

When the Bell X-1 airplane broke the sound barrier in 1947, an aeronautical dream was finally realised – supersonic flight. Concorde famously followed suit in 1969, but it failed to remain commercially viable and was retired in 2003. The Aerion AS2 plans to succeed where Concorde failed.

This aircraft will be fundamentally different to its predecessor, sporting a number of critical improvements. The triangular, 'delta' wing shape of Concorde is replaced by smaller, thinner wings, with the addition of a horizontal stabiliser. Rather than trapping air around the wings to produce a turbulent airflow, the new streamlined design reduces drag (the frictional force caused by the air surrounding a moving object) on the wings by around 70 per cent. Aerion has named this technology 'Supersonic Natural Laminar Flow', which should allow the AS2 to punch through the sound barrier using just a standard jet engine.

Similar to modern fighter jets, the AS2's wings are made of carbon fibre, keeping them light and durable, with the addition of a titanium edge, to resist erosion. The combination of the wing, tail and airframe design should lead to an overall drag reduction of 20 per cent, a huge leap forward in efficiency. This keeps fuel consumption at a minimum, boosting the aircraft's range, and allows for a luxurious cabin with space for 12 passengers.

One drawback of supersonic flight is the loud sonic boom it creates; most countries would rather this wasn't happening in their airspace. Once built, it's hoped that the AS2 will be able to perform a 'boomless cruise' at Mach 1.2, by flying in certain atmospheric conditions. Depending on air temperature and wind, the shockwaves created as the AS2 breaks the sound barrier would dissipate before they reach the ground, meaning that the population below the plane wouldn't hear the deafening boom.

The AS2's passengers will be treated to luxurious seating and incredible views through large windows

Aerion hope to complete an AS2 prototype within the next five years

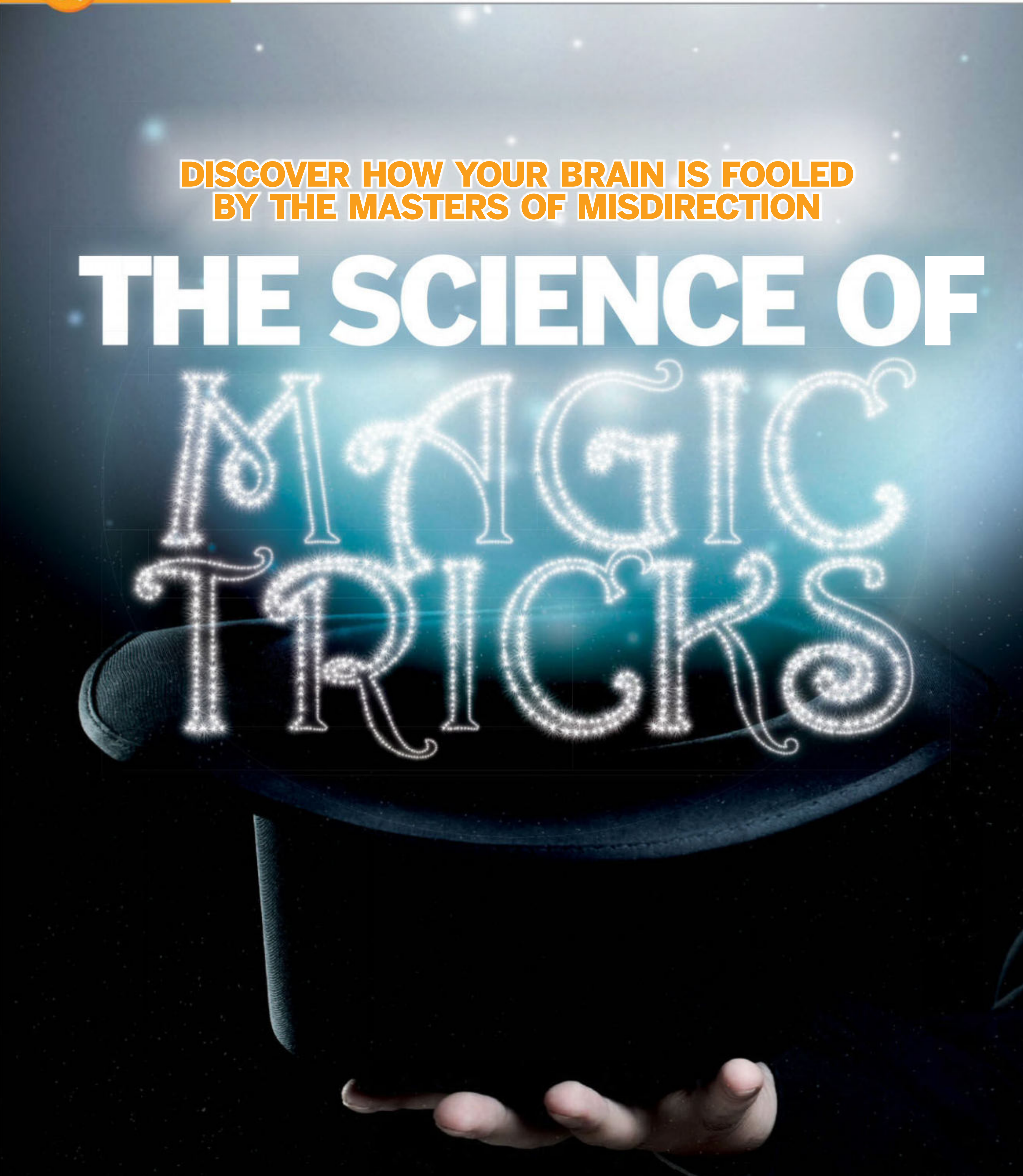
Concorde's famous delta wing design was iconic, but actually reduced the plane's efficiency

STATS

Max speed: Mach 1.5 (1,852km/h)
Max range: 9,816km
Length: 51.8m
Wingspan: 18.6m
Passengers: Up to 12
Wing area: 125m^2
Cost: £82 million ($120 million)

DISCOVER HOW YOUR BRAIN IS FOOLED BY THE MASTERS OF MISDIRECTION

THE SCIENCE OF MAGIC TRICKS



"Magicians are connoisseurs of human behaviour and perception"

A magician must make a trick look effortless, but there is very little that is casual or spontaneous in a magic show. If you are lucky enough to watch a performance by a sleight-of-hand master such as Teller (of the magic duo Penn & Teller), Johnny Thompson or Juan Tamariz, chances are that nothing has been left to chance. Though other artistic fields also make performances look easy, magic is on a different plane.

Think of it this way: if you go and see George Balanchine's *The Nutcracker* by the New York City Ballet, you will have no trouble imagining all the sweat and tears that must have gone into achieving those amazing dance moves. Your body can't do that, and you know it. Magic is just as choreographed, of course, but the nature of the art is that it must not look so. The motions of the hands and body must look like the ones you naturally make every day. Yet, even a causal drop of the magician's shoulders – which the audience will hopefully not notice or remember after the show – can be filled with purpose and intent. That shoulder drop might have been the weapon of magical murder.

Artists of all kinds, including magicians, are connoisseurs of human behaviour and perception, and strive to evoke particular experiences in their audience. Magicians can alter a spectator's perception in a variety of ways, but their speciality is attention management – known as misdirection. The concept of misdirection is often misunderstood. Audiences may believe that the magician distracts their attention during a critical move or manipulation, but this is not correct. They do not strive to turn spectators' attention away from the 'method' – the secret behind the magic trick – but instead aim to direct their attention towards the magical effect. This is a critical point, and the reason it works is grounded in neuroscientific findings about the way our attention is controlled – a bit like a spotlight – by the brain.

The spotlight of attention is a metaphor used by neuroscientists and magicians alike and refers to the fact that we aim our attentional focus like a flashlight. Whatever object, person, or action we concentrate on appears more salient and even brighter than the rest of the scene. However, the neuroscience informs us that there is one fundamental difference between your attentional spotlight and your iPhone's torch app. The reason things become more noticeable when you attend to them is not that your neural circuits boost your perception to make you more focused, but that everything else is actively suppressed. In other words, the spotlight of attention only seems to shine by comparison to the surrounding darkness. This means that magicians need only ensure that audiences aim their attention to specific spatial locations on the stage, and each spectator's brain will take care of suppressing everything else – including the secret method hiding behind the magical effect. In a very real sense, your brain is the magician's assistant.

Research suggests that these enhancement and suppression processes are mediated by two different populations of neurons in the visual cortex – the area at the back of the brain that processes visual information. How do magicians, then, drive the audience's attention to particular places and time intervals during a performance? One effective way to misdirect somebody's attention is by changing where they are looking. Magicians employ various

Meet the experts

Susana Martinez-Conde and Stephen L Macknik are neuroscientists and laboratory directors at the State University of New York Downstate Medical Center. They are the authors of *Sleights of Mind: What the Neuroscience of Magic Reveals About Our Everyday Deceptions*, and magician members of the Academy of Magical Arts in Hollywood and the Magic Circle in London.

strategies to control your eye position. These include asking specific questions about particular items on stage ("Tell me what card this is," or "What is the year on this coin?") and using their own body language and gaze direction to induce joint attention behaviours in the audience.

Joint attention is the mechanism that makes us gaze at something when we see other people doing it. For example, if you see a crowd of people looking up in the street, you will find it irresistible to look up as well. If the magician wants the audience to look at a specific object, he himself will pretend to be completely absorbed by it. However, if the magician wants the audience to look at his face, he will direct his own gaze to the rows of seats – even if he cannot actually see the audience due to the stage lighting – and the spectators will reciprocate.

Yet magicians can be subtler than just misdirecting your gaze. They do not necessarily have to change the audience's direction of gaze in order to shift their attentional focus. When they succeed, audiences are looking at the right place, though without seeing, because their attention is engaged elsewhere. It's powerful magic indeed. One way to mess with somebody's attention, without diverting their gaze at all, is to split their focus. The same attentional neural mechanisms that boost our perception (at the centre of the spotlight) and suppression (in the surrounding areas) make it very difficult for us to multitask. We have a single attentional focus, which cannot be divided without losing effectiveness.

Magicians get audiences to multitask in a variety of ways. One such strategy is the very design of certain magic tricks. One prime example is the 'cups and balls' trick, one of the oldest magic tricks known – there are even records of performances taking place in Ancient Rome! It is usually performed with three cups placed upside down on a table. Balls and other objects magically appear and disappear inside the cups, much to the audience's amazement. The way the performance is arranged forces spectators to split their attention between a minimum of three places on the table (the inverted cups), making their focus at most a third as precise as it might have been had they attended to a single location. The tactic is to divide the audience's attention and conquer their perception of what is happening.

Another way to make spectators try to multitask is to engage their senses and their mind in multiple ways simultaneously. Apollo Robbins, a world-renowned theatrical pickpocket, uses sight, sound (patter) and touch (tapping various parts of a volunteer's body onstage) to misdirect attention away from the pocket or wrist that he intends to steal from. Many other magicians also use rapid fire 'patter' to overwhelm the audience's auditory and language processing capabilities. So when Penn is talking a million words a minute on stage, what he's actually doing is bombarding you with information to keep your brain busy.

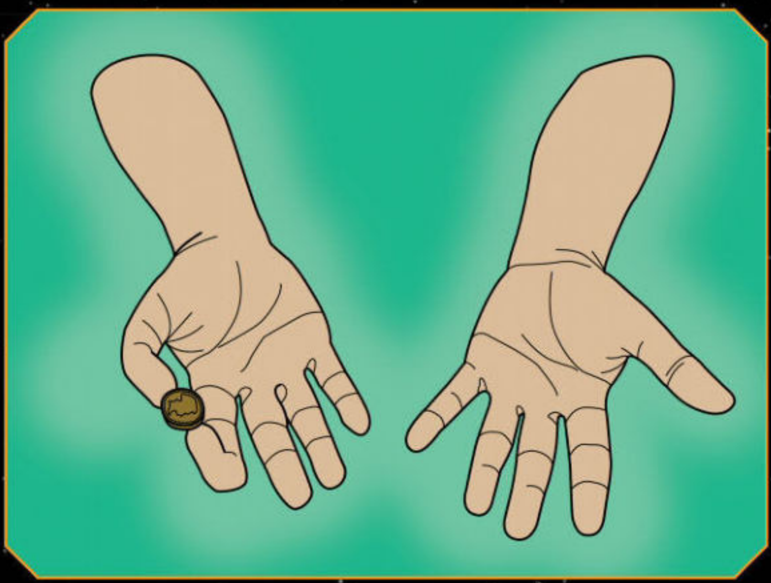
One main goal is to create 'internal dialogue' in each spectator: if audience members are having even a simple inner discussion with themselves, they won't be focusing as much on what's going on right in front of their eyes. The Spanish magic theorist Arturo de Ascanio advised magicians to "ask a discombobulating question". Even by asking: "Has anybody

The art of misdirection

How can a magician make a coin disappear?

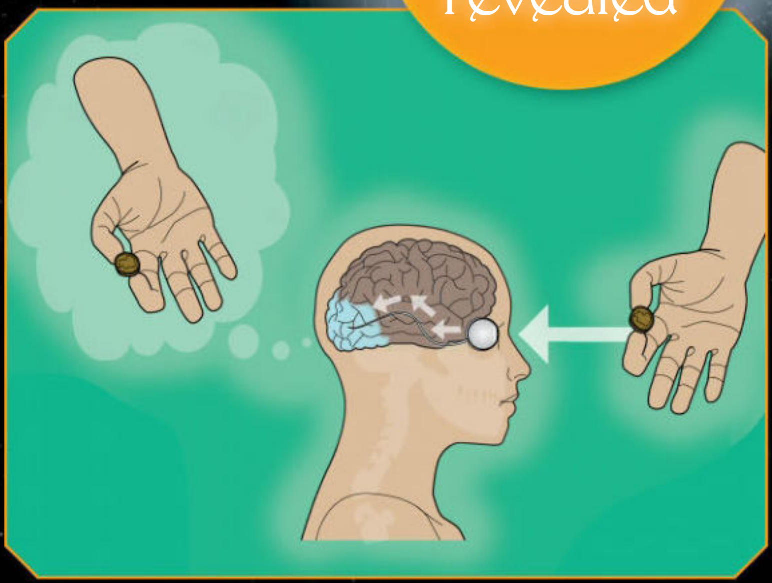
Spoiler alert! Magic secrets revealed

One classic method to make a coin or another small object vanish is known as the French Drop, or Le Tourniquet. This sleight-of-hand technique was popularised in the late 1800s by the father of modern magic, Jean Eugène Robert-Houdin – after whom Houdini took his stage name – and is usually performed in the following sequence…



Show and tell

The magician shows and manipulates a coin between the thumb and fingers of their right hand. The coin is clearly visible to the audience at this stage, but with a few sneaky tricks they can be decieved with surprising ease.



False take

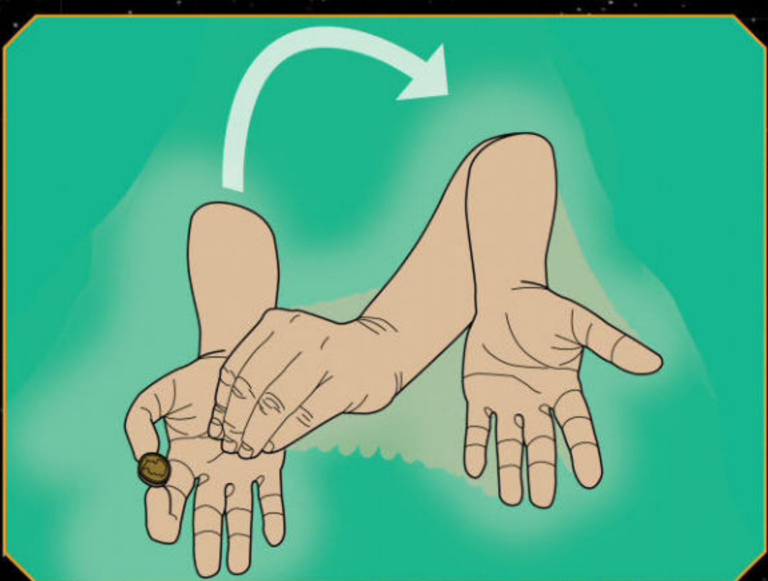
Light reflecting off the coin passes to the viewer's retina. From here, signals are sent to the visual cortex where a mental image is formed. The magician's left hand approaches the right, and pretends to take the coin from the fingertips. This is known as a false take.

Why do we follow movement?

Our visual systems have evolved to detect motion. Movement across the visual field can indicate the approach of a predator, or the escape of prey; it is inherently interesting to our brains, and automatically engages our attention in a reflex manner. Not all types of motion are equally salient, though. Magicians say that "a large motion covers a small motion", by which they mean that a large, highly noticeable manoeuvre will hide a tiny but critical manipulation.

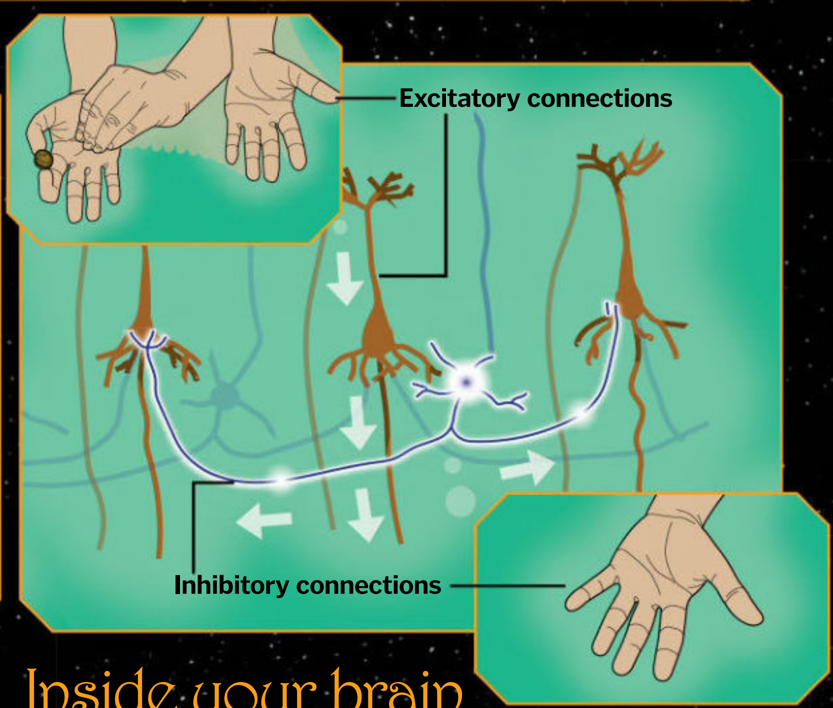
In our own research – conducted in collaboration with magician Apollo Robbins – we found that the curved motion of the magician's hand is more engaging to spectators than straight motion. One reason is that motion in a straight line is much more predictable than curvy motion. Whereas we only need the beginning and end points of a linear path to define it completely, a motion arch forces us to stay on target throughout, inadvertently missing the magician's sleight of hand.

Magicians carefully plan their movements to direct the audience's attention away from their manipulation



Arc motion

The magician's left hand moves away from the right, all the while appearing to still carry the coin. The moving-away motion activates excitatory connections in the part of the brain processing the 'pretending hand,' so we notice it more as a result.



Inside your brain

At the same time, inhibitory connections suppress the part of the brain that is processing the visual input of the original hand. As a result, the magician's right hand becomes quite unnoticeable. Unknown to the audience, this hand still holds the coin.

brought a scarf?" will get each spectator to ponder the question for a second or two. During that brief interval, they are trapped within their heads and unable to process other inputs efficiently; the magician is free to perform the secret move.

Emotion is also used to the magician's advantage, as feelings and attention are pretty incompatible. This is one main reason why eyewitness reports are famously unreliable. If you find yourself in the situation of having to give testimony in court or file a police report about something you witnessed, it's highly likely that the event in question led you to experience a strong emotion. Human memory is certainly limited, and more so when you are scared. Some magic performances contain horror or gory elements – one of Teller's signature tricks is to 'drop' a cute rabbit into a wood chipper – but humour is the emotion that magicians choose to provoke most often. Hilarity in a magic show increases the entertainment value and hampers the spectators' ability to concentrate. Johnny Thompson (also known as The Great Tomsoni) says that while the audience laughs, time stops. It's during this interval that the magician is safe to make a move, perhaps in preparation for the next trick.

How is it that magicians have arrived to such a refined understanding of human nature? One answer is that, whereas the field of cognitive neuroscience – the study of mental processes – is only a few decades old, the magical arts have been around for a very long time. Magicians have had millennia to figure out what works and what doesn't. Spanish magician Miguel Angel Gea says that each performance is an experiment; every trick puts a hypothesis to the test. Even without applying the scientific method in any rigorous fashion, it makes sense that magicians must have figured out a thing or two about cognition and perception. Even if they have no better methods than trial-and-error, they are smart people doing serious analyses of the human condition; they will eventually discover a few important facts.

It is only recently that the neuroscientific community has come to appreciate how magic can conjure new insights into the human brain. In 2008, we coined the word 'neuromagic' and today, more than a dozen laboratories around the globe have conducted studies on the neural bases of magic performances. Whereas not all magic theories have panned out in the lab, it has also become apparent that cognitive neuroscience, as a discipline, has reinvented the wheel sometimes – arriving to conclusions that magicians had held true for quite a while. It may be that these amateur brain hackers still have some tricks up their sleeves that can help advance neuroscientific discovery.

It's a kind of magic

All magic tricks follow certain central themes…

Even a short magic routine may include a variety of illusions: perceptual experiences that do not match reality. Magicians like to pile up illusions on top of each other, to bulletproof their tricks. When that happens, spectators have no hope of peeling away all the illusory layers to get to the magic secrets underneath, at least not during the course of the performance.

Optical illusions
Think of smoke and mirrors. Like a pencil in a glass of water that appears to bend, these are illusions that rely on the physical properties of light.

Cognitive illusions
These involve higher cortical areas of the brain that are involved in processes such as attention, memory and decision-making. Magicians manipulate all of these.

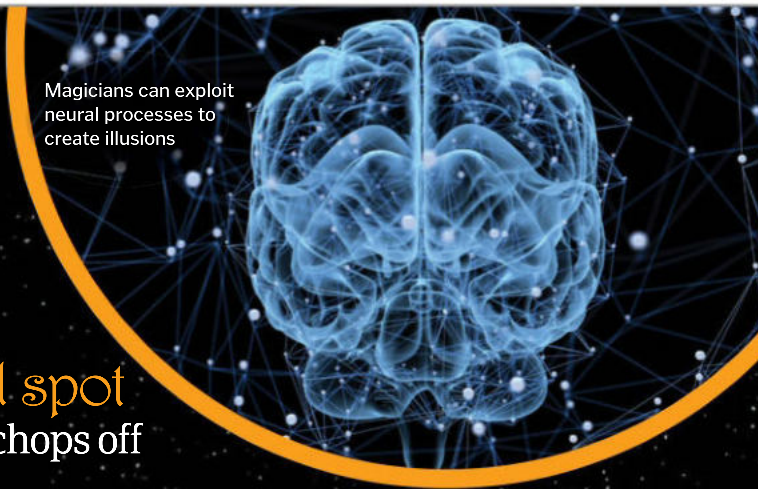
Visual illusions
Unlike optical illusions, which are explained by the physics of light, visual illusions are constructed in the brain. An example of this is the filling-in of the blind spot.

Special effects
Just like when you go to the movies, special effects in a magic show can include fake gunshots and explosions, adding drama to the occasion.

Other sensory illusions
Magicians occasionally employ tactile and auditory illusions, sometimes in combination with visual information, to create multisensory misperceptions.

Mechanical devices and secret compartments
Magic tricks can use simple or sophisticated technology to fool the audience. Magicians refer to such contraptions as gimmicks.

How your brain fills in the gaps



Magicians can exploit neural processes to create illusions

Thinking is metabolically expensive. The brain represents only two per cent of our total body weight, but it uses more energy than any other human organ, accounting for up to 20 per cent of the body's total. Even that much energy is not enough to process the vast amount of information that constantly bombards our senses, so our brains have evolved to take shortcuts.

One such shortcut is a neural process called filling-in. A spectacular example of this takes place at the blind spot: a big gap in your retina, devoid of photoreceptors, where the optic nerve leaves the eye on its way to the brain, near the very centre of your vision. Luckily, the brain is good at guessing what should be there, so we rarely notice any gaps in the world around us.

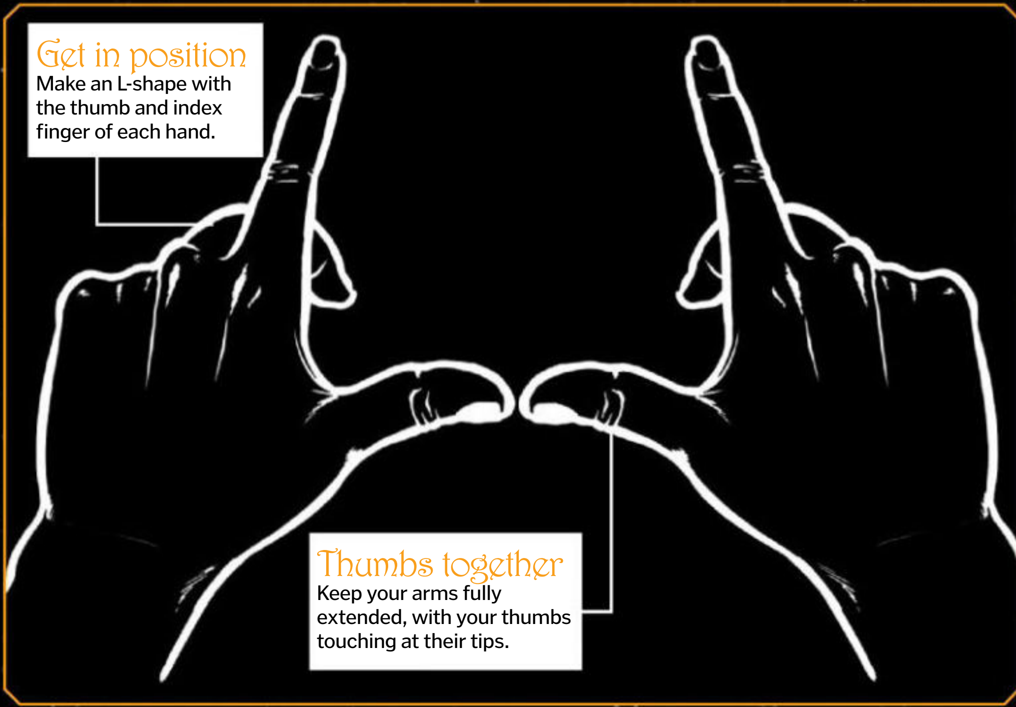
To find your blind spot, extend both arms in front of you, with your elbows straight. Make an L-shape in each hand with your thumb and index finger, while keeping the other fingers curled inside your fists. Without bending your elbows, touch both thumbs together. Now close your left eye and look at your left index fingertip. Without changing your gaze, pay attention to the tip of your right index finger, and notice that it has disappeared. Your index finger now ends right above the second or even the first knuckle. If the fingertip remains visible, wiggle the finger a little bit left and right to make it enter the blind spot region.

It is said that King Charles II of England used a similar party trick to decapitate prisoners before beheading them for real. Once your fingertip is gone, try to see what is occupying the same visual space. Do you see a great big black hole? No, there is no gap where your finger should be. Instead, it feels as if you can see what is behind the finger. Yet that is impossible.

What is actually happening is that your brain is using the information about the textures and colours surrounding your finger to fill in the visual void at the blind spot. It is a pretty good algorithm, but not smart enough to reconstruct your actual finger. How our brains fill in the blind spot in our retinas is a dramatic example of how we fill in many other perceptual and cognitive gaps, not only in magic performances, but also in our everyday lives.

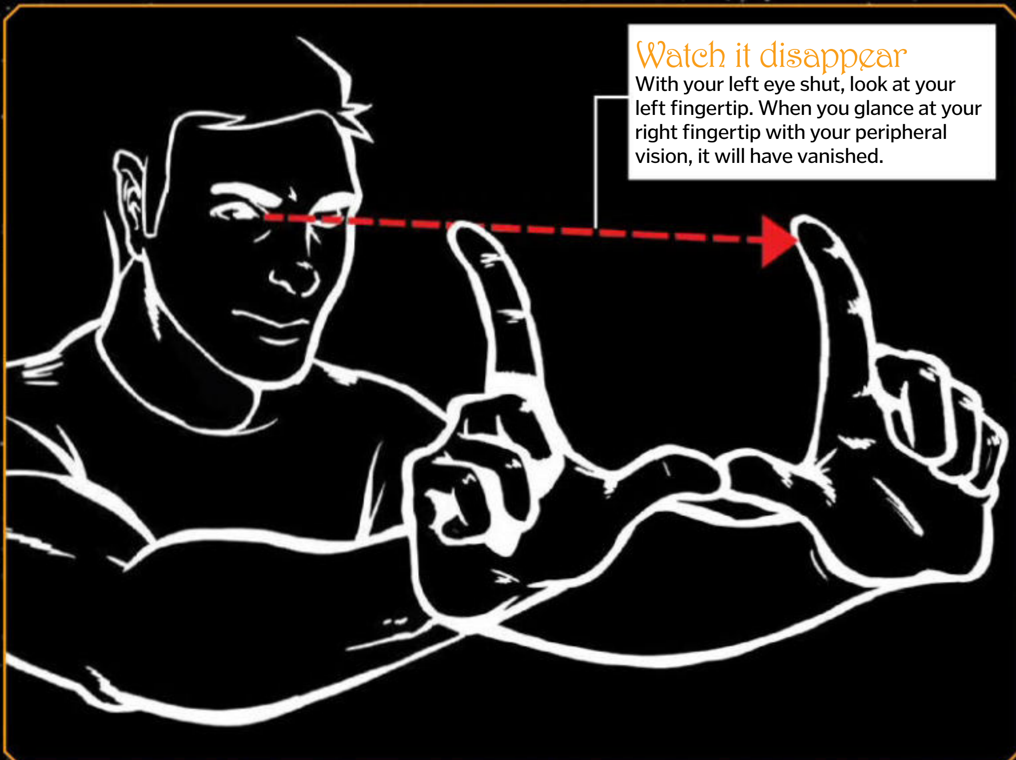
Find your blind spot

Watch as your brain chops off your fingertip



Get in position
Make an L-shape with the thumb and index finger of each hand.

Thumbs together
Keep your arms fully extended, with your thumbs touching at their tips.



Watch it disappear
With your left eye shut, look at your left fingertip. When you glance at your right fingertip with your peripheral vision, it will have vanished.

How cavities form

Avoid a trip to the dentist by learning about how to prevent tooth decay

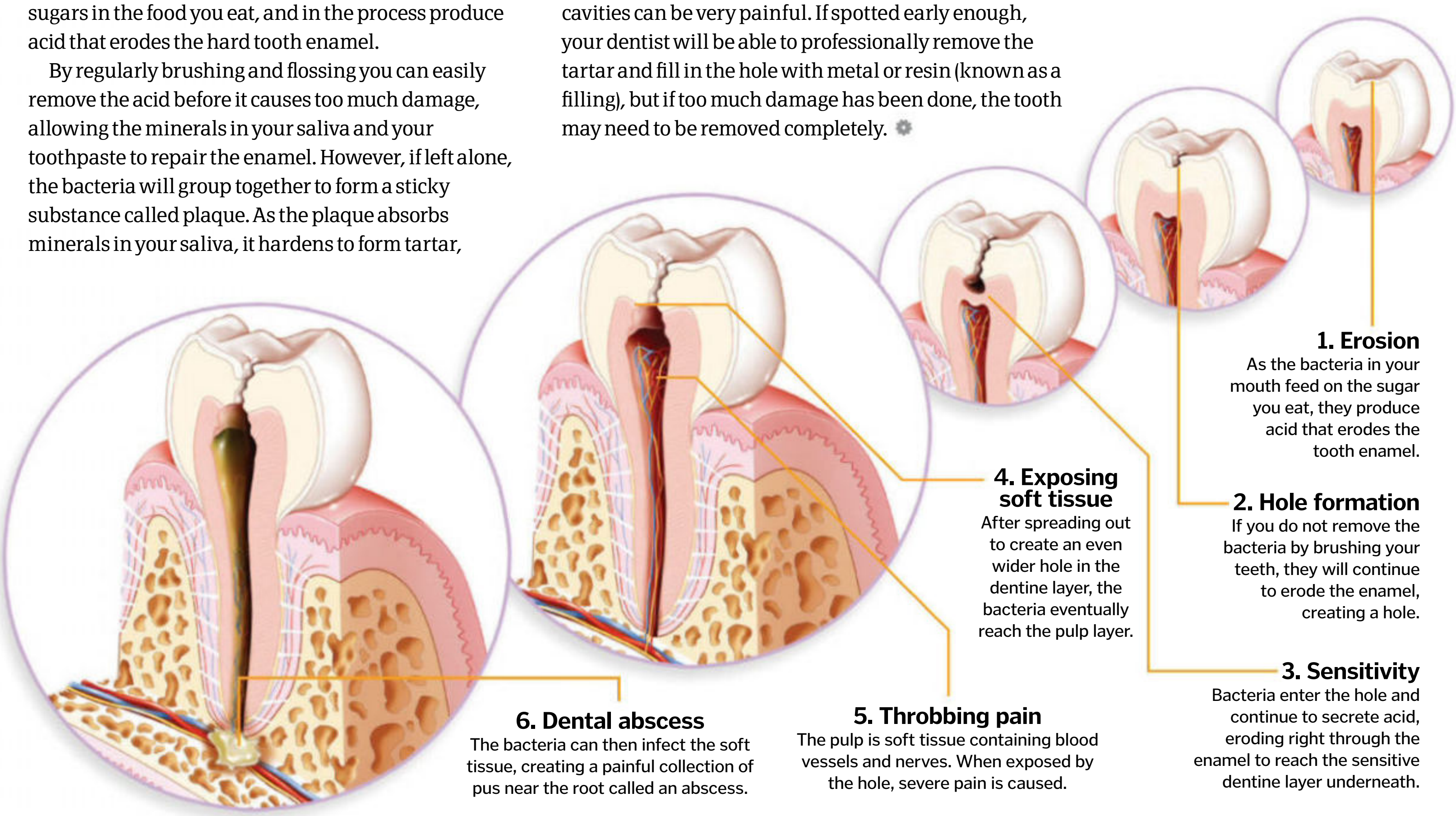
Our mouths are full of bacteria. Some are helpful, but others can create painful holes in your teeth called cavities. The harmful bacteria feed on sugars in the food you eat, and in the process produce acid that erodes the hard tooth enamel.

By regularly brushing and flossing you can easily remove the acid before it causes too much damage, allowing the minerals in your saliva and your toothpaste to repair the enamel. However, if left alone, the bacteria will group together to form a sticky substance called plaque. As the plaque absorbs minerals in your saliva, it hardens to form tartar, which protects the bacteria so they can continue to erode your teeth and form deep holes known as cavities.

As they expose the sensitive inner layers of your tooth, cavities can be very painful. If spotted early enough, your dentist will be able to professionally remove the tartar and fill in the hole with metal or resin (known as a filling), but if too much damage has been done, the tooth may need to be removed completely.

Cavity creation

How bacteria erode your teeth right to the root



1. Erosion
As the bacteria in your mouth feed on the sugar you eat, they produce acid that erodes the tooth enamel.

2. Hole formation
If you do not remove the bacteria by brushing your teeth, they will continue to erode the enamel, creating a hole.

3. Sensitivity
Bacteria enter the hole and continue to secrete acid, eroding right through the enamel to reach the sensitive dentine layer underneath.

4. Exposing soft tissue
After spreading out to create an even wider hole in the dentine layer, the bacteria eventually reach the pulp layer.

5. Throbbing pain
The pulp is soft tissue containing blood vessels and nerves. When exposed by the hole, severe pain is caused.

6. Dental abscess
The bacteria can then infect the soft tissue, creating a painful collection of pus near the root called an abscess.

Is it better to walk or run in the rain?

Find out how quick you should move to avoid a soaking

When you're caught in a rain shower without your umbrella, do you sprint to shelter so you spend less time getting wet, or take it slow to avoid running into more raindrops from the side?

Strictly speaking, staying still is your best option. If you're not moving, you'll only be hit by rain from the top, not from the side, so fewer raindrops will hit you overall. However, if you're trying to get somewhere dry, standing still won't be very helpful.

If you're on the move, then the amount of rain that hits the top of you will be the same regardless of how fast you're going, because when you move out of the way of one falling raindrop, you move into the way of another. The same can also be said for the amount of rain you run into from the side, as no matter how fast you're going, the same number of raindrops will hit you over a given distance.

Therefore, to stay as dry as possible when moving from point A to point B, the best approach is to minimise the amount of water that hits you from above, which means getting out of the rain as quickly as possible. Run for it!

You'll stay drier by running out of the rain as opposed to walking

60 SECOND SCIENCE

Sound waves

THE PHYSICS BEHIND THE NOISES YOU HEAR

BACKGROUND

Sound is created by vibrations passing through particles in solids, liquids and gases. These vibrations create sound waves and when these reach your ear, they are interpreted by your brain as sound.

Sound waves are longitudinal, which means they vibrate in the same direction as they travel, and can reflect off certain surfaces to create an echo. The shape of a sound wave can be shown by an oscilloscope machine and reveals a lot about the kind of sound created.

IN BRIEF

The frequency of sound waves is measured in hertz (Hz). Humans can only hear sounds between 20 and 20,000 Hz, as above this they are too high-pitched for our ears to register. However, this high frequency sound, known as ultrasound, can be heard by certain animals, including dogs and cats, and is very useful in medicine.

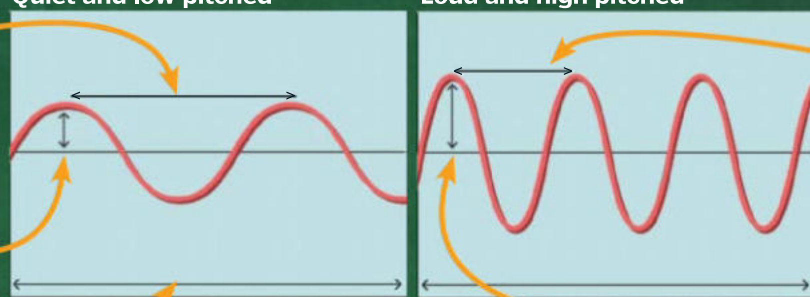
When ultrasound waves reach a boundary between two substances that have different densities, some of them are reflected back, a bit like an echo. By measuring the time it takes for the waves to bounce back, the distance to the boundary can be calculated. This is used to scan babies in the womb, as the boundary between the fluid in the womb and the baby's soft tissue can be used to create an image of the unborn child.

SUMMARY

Sound is vibrations through air, liquids or solids that are converted by your brain into electrical signals. The shape of the sound waves determines the volume and pitch of the sound.

Sound wave properties

What do the wiggly lines actually mean?



Wavelength
The wavelength is the distance between two identical points (e.g. the peaks) of two sound waves next to each other.

Amplitude
The amplitude is the maximum height of the sound wave from its resting position.

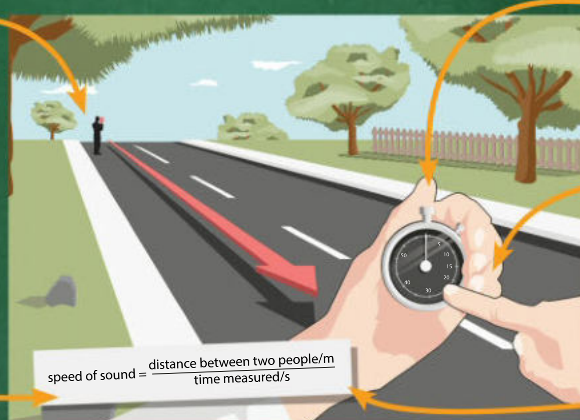
Frequency
The frequency is the number of sound waves created per second.

Volume
The greater the amplitude of the wave, the louder the sound created.

Pitch
The shorter the wavelength, the higher the frequency of the wave and the higher the pitch of the sound created.

Calculating the speed of sound

A simple sound experiment you can try at home



Making noise
Get a friend to stand 100 metres away from you and bang two sticks together.

Speed of sound
Your calculation will give you the speed of the sound as it travelled through the air.

Start recording
As soon as you see your friend bang the sticks together, start your stopwatch.

Stop the clock
When you hear the sound of the sticks banging together, quickly pause the stopwatch.

Do the maths
Divide the distance between you and your friend in metres by the number of seconds on your stopwatch.

THE SPEED OF SOUND

THE SPEED OF A SOUND WAVE DEPENDS ON WHAT IT IS PASSING THROUGH. IT TRAVELS THROUGH AIR AT ABOUT 340 METRES PER SECOND, BUT MOVES OVER FOUR TIMES FASTER THROUGH WATER AND QUICKER STILL THROUGH CERTAIN SOLIDS. HOWEVER, IT IS STILL NOT AS FAST AS LIGHT, WHICH TRAVELS THROUGH AIR AT JUST UNDER 300,000,000 METRES PER SECOND. THIS IS WHY YOU CAN SOMETIMES SEE THE SOURCE OF A SOUND BEFORE YOU HEAR THE NOISE ITSELF. IF AN OBJECT TRAVELS FASTER THAN THE SPEED OF SOUND, IT FORCES THE SOUND WAVES IT CREATES TOGETHER INTO ONE SHOCKWAVE. THIS IS INTERPRETED BY YOUR BRAIN AS A LOUD SONIC BOOM, AND IS WHAT YOU HEAR WHEN AN AIRCRAFT BREAKS THE SOUND BARRIER, A WHIP CRACKS OR A BALLOON POPS.

Carbon and nitrogen cycles

How nature's excellent recycling skills create the perfect balance of the matter that really matters

While we might not be very good at recycling our waste, nature does a much more efficient job. Using various clever processes, it ensures that carbon and nitrogen, two of the most important elements for all living organisms, are put to good use, even when plants and animals no longer need them.

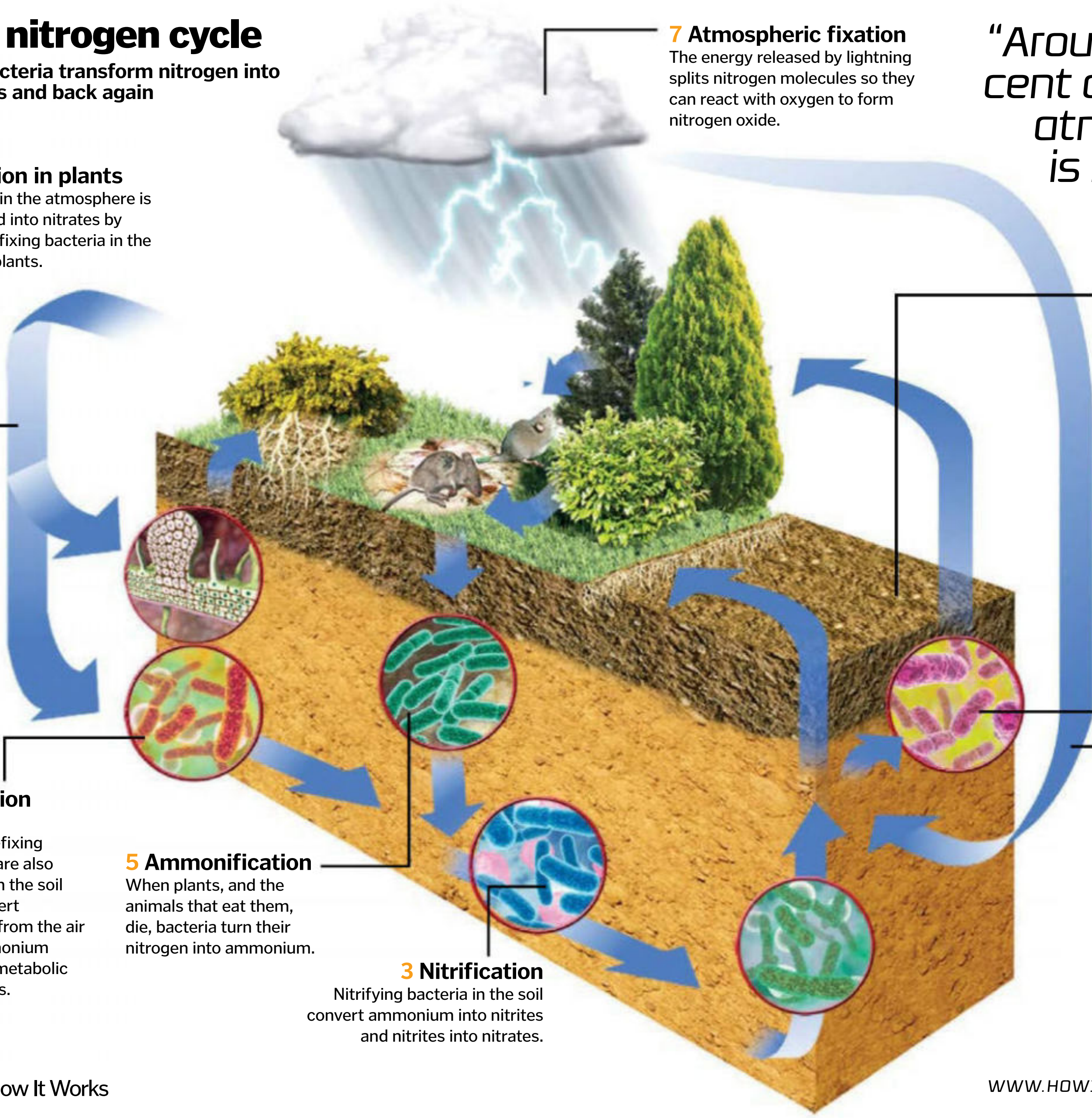
The nitrogen cycle is essential for all living things, as this element is needed to produce proteins and DNA – the building blocks of life. It is also used by plants to create chlorophyll, the compound that they need to photosynthesise and grow.

Although around 78 per cent of the Earth's atmosphere is nitrogen, plants cannot absorb it in this unreactive form. Therefore it's up to bacteria in soil to convert it into compounds that plants can make use of. Gradually these pass through the food chain, until more bacteria reverse the process and return it back into the atmosphere as nitrogen.

However, human involvement is disrupting the balance. The synthetic nitrogen fertilisers we have created to boost agricultural productivity have increased the amount of nitrogen being washed into rivers and lakes. This is not only harmful to the organisms that live in the water, but also to those that drink it, such as humans and animals.

The nitrogen cycle

How bacteria transform nitrogen into proteins and back again



> "Around 78 per cent of Earth's atmosphere is nitrogen"

Excess nitrogen in water and soil can also enter the atmosphere as nitrous oxide. This greenhouse gas is a major factor in the formation of smog, causing respiratory illnesses in humans, and acid rain, which is responsible for killing many plants.

Carbon is another key component for all forms of life, and makes up 18.5 per cent of the human body. It can also be found in the air we breathe, in the ground beneath our feet and in the fuels that we burn.

Living things get their supply of carbon from the air around them or the food they eat, but when they are finished with it, the substance quickly gets recycled. Some is transferred straight back into the atmosphere through respiration, while the rest finds its way into the ground after the organism has died. Here it is fossilised and stored for millions of years beneath the Earth's surface until it is removed through natural or human processes.

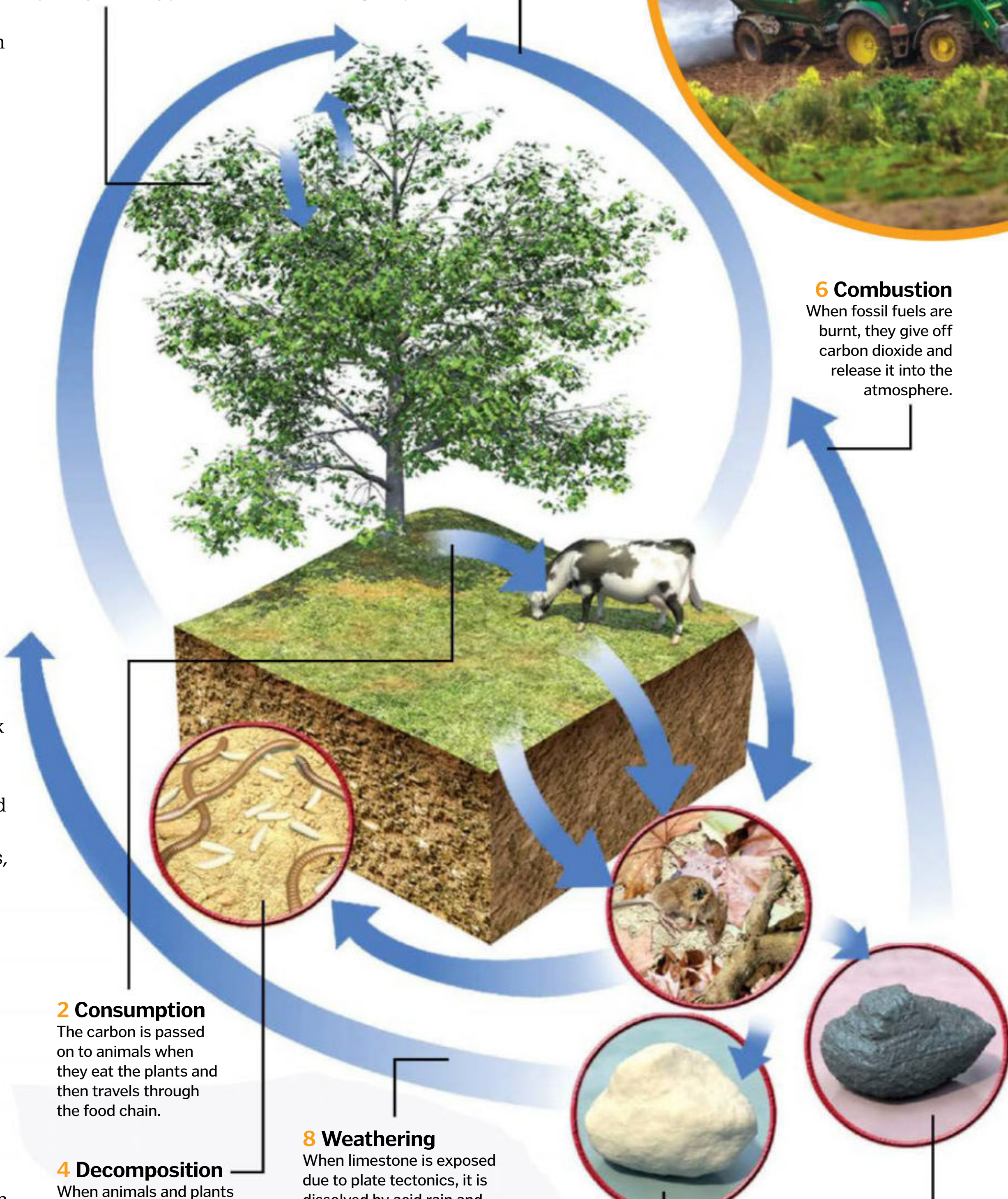
Much of the carbon stored in limestone rock beneath the ocean is released thanks to plate tectonics. As the plates move, some sections of the seafloor become exposed as land, where acid rain can dissolve it and release the carbon back into the air. However, in other areas, sections of seafloor are pushed beneath others, heating up as they do so. This causes the rock to melt, sending carbon back into the atmosphere via hot springs, vents or volcanic eruptions.

The rest of the carbon in the ground eventually becomes fossil fuels, which we extract to power our homes, factories, vehicles and more. When the coal, oil and gas are burnt, the carbon within is released as carbon dioxide, and this is what is throwing the cycle out of balance. The increased rate at which we are burning fossil fuels means that the amount of carbon dioxide released into the atmosphere has accelerated.

On top of this, deforestation has led to there being fewer plants to remove carbon dioxide from the air, causing the atmospheric carbon concentration to increase further. As carbon dioxide holds heat in the Earth's atmosphere, this is causing global climate change that will have a big impact on the future of our planet.

The carbon cycle

How carbon is recycled to create plants, fuel and you



1 Photosynthesis
Carbon dioxide is removed from Earth's atmosphere through photosynthesis by plants.

3 Respiration
Most of the carbon the animals eat is released back into the air as carbon dioxide through respiration.

6 Combustion
When fossil fuels are burnt, they give off carbon dioxide and release it into the atmosphere.

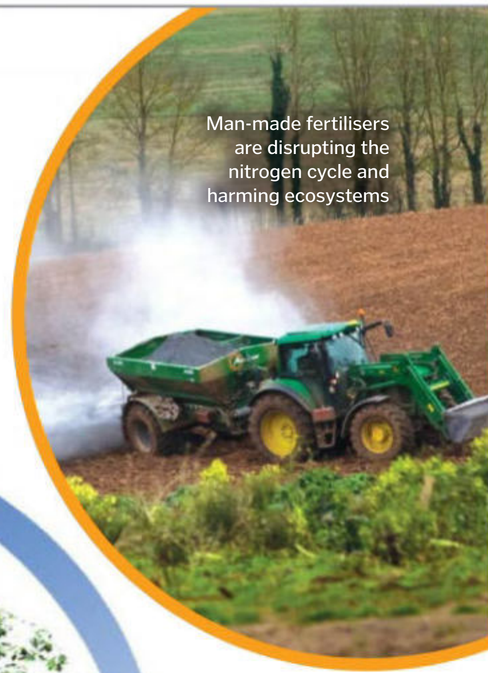
2 Consumption
The carbon is passed on to animals when they eat the plants and then travels through the food chain.

4 Decomposition
When animals and plants die, they are eaten by living organisms, which converts some of the carbon back into carbon dioxide.

8 Weathering
When limestone is exposed due to plate tectonics, it is dissolved by acid rain and carbon dioxide is released.

7 Limestone
In the ocean, marine animals use carbon to make their shells and when they die, these break down to form limestone.

5 Fossil fuels
As the animal and plant remains become buried, heat and pressure eventually turn them into fossil fuels such as coal.

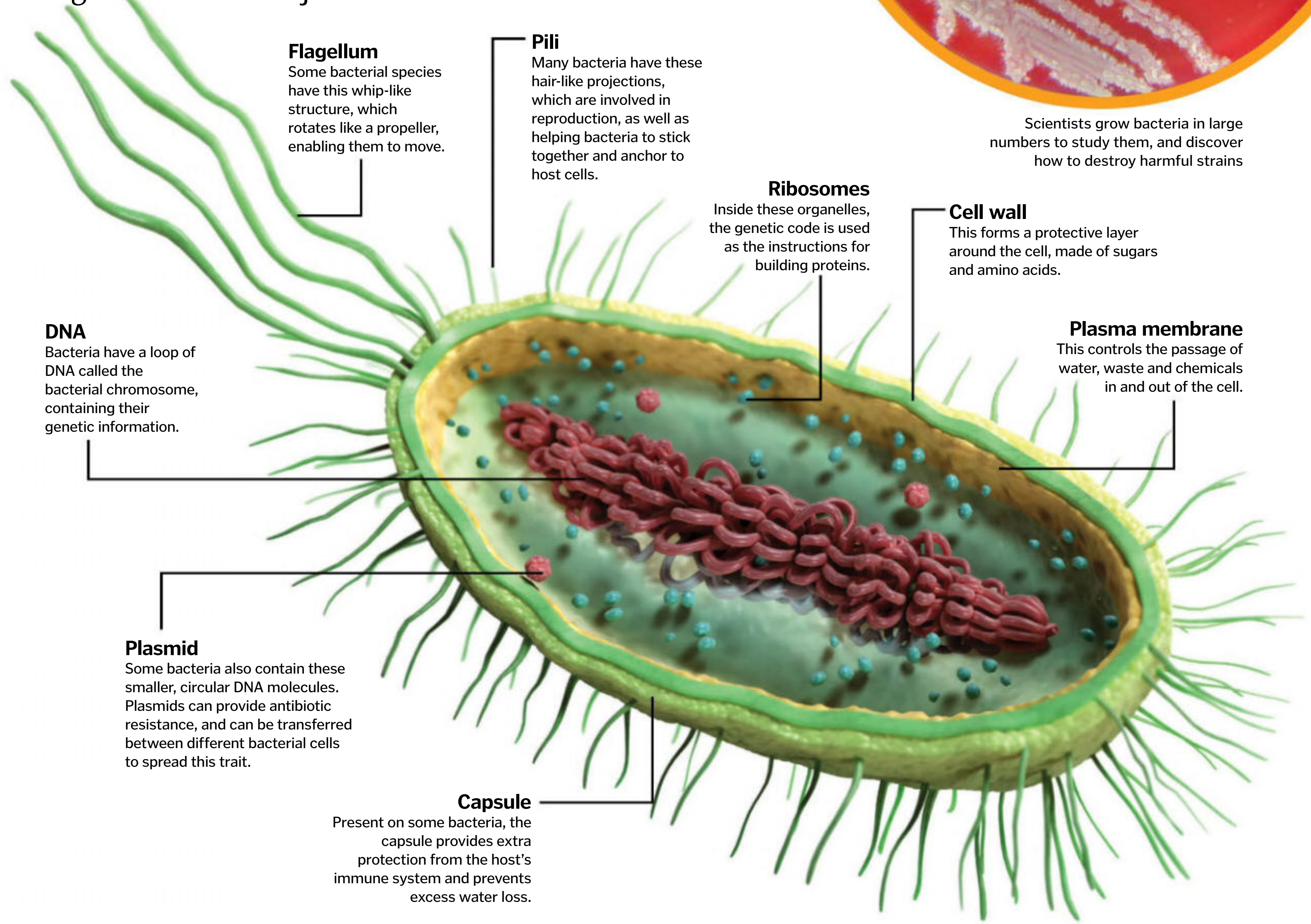


Man-made fertilisers are disrupting the nitrogen cycle and harming ecosystems

Inside bacteria

Get up close with these incredible organisms made of just one cell

Scientists grow bacteria in large numbers to study them, and discover how to destroy harmful strains



Aftershave science

There's more to this cosmetic than the smell

Unlike a perfume or cologne, aftershave's primary function is to protect the skin from infection. When you shave with a razor, the blades often irritate your skin, creating a series of small cuts. To safeguard against infection, aftershave contains an antiseptic – traditionally alcohol – to kill off bacteria before they can penetrate the skin.

Witch hazel has become a popular alternative to alcohol, and is now readily available in aftershave balms. This naturally occurring compound is produced from shrubs of the same name. It contains chemicals called tannins, which provide astringent (making tissues contract to help stop any bleeding) and anti-inflammatory (reducing swelling) properties.

A problem with using alcohol or witch hazel in aftershaves is that both substances dry the skin out. Many aftershave balms or milks also contain moisturisers to help replenish any water lost, keeping your skin hydrated and feeling fresh.

The presence of alcohol or witch hazel can cause the stinging sensation associated with some aftershaves

The physics of golf swings

How science can help you power the perfect drive

When using a driver, the club remains in contact with the ball for only 0.0004 seconds

Circular motion

Centripetal force holds an object in circular motion and generates the power in a swing. Anything in motion naturally wants to move in a straight line; a golfer has to fight against this to force the club in a circular path. The shoulder hinge creates the centripetal force to pull the club around. The force builds during the swing as the arms are extended, until the club forms a straight line with the arms and strikes the ball.

Double pendulum effect

Golf swings are made up of two interconnected pendulums. The upper pendulum – the arms and hands – swings from the shoulders, which represent the fixed pivot point in the swing. The second pendulum – the club head and shaft – is joined to the upper pendulum at the hands and wrists. It's vital that both pendulums reach the impact zone (when the club hits the ball) at the same time; otherwise some energy will be lost.

Creating torque

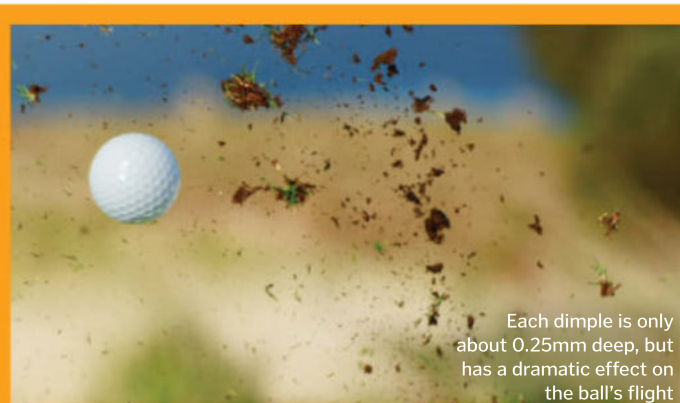
Torque is a force that causes things to turn or rotate. In golf, torque is created by a golfer's body as it twists around the spine. Firstly, the shoulders and hips rotate away from the ball when the club is lifted. When the club is swung, energy is generated by rotating the hips towards the ball and allowing the shoulders, arms and wrists to follow. The more torque that is applied, the more powerful the shot.

Why do golf balls have dimples?

Before golf balls had dimples, golfers noticed that older balls would travel further than newer ones. They discovered that this was due to the scuffs and scratches that formed over time, and set about incorporating them into new balls in the form of dimples. Several hundred of these tiny 'divots' were added, helping the modern golf ball to travel around twice as far as a smooth alternative.

When a golf ball is struck, the air flowing closest to the ball – the boundary layer – detaches from the surface around the ball's rear. This creates a low-pressure zone, which pulls on the ball and slows it down. Adding dimples forces tiny pockets of turbulence to form as the ball travels, which helps the boundary layer to stick to the ball for longer. By keeping the airflow attached, the drag on the ball is reduced, which keeps it moving through the air.

The dimples also increase the ball's lift, helping it to stay airborne. This is thanks to Bernoulli's Principle – as the speed of the airflow is increased, the pressure decreases, which creates the extra lift.



Each dimple is only about 0.25mm deep, but has a dramatic effect on the ball's flight

How do woks work?

Serving up the science behind the perfect stir-fry

It may look like a simple pan, but the humble wok is the secret to cooking authentic Chinese food. It's essential for creating what the Chinese call 'wok hei' or 'breath of the wok', the unique taste of wok-cooked cuisine, which is a result of the pan's clever design and some serious seasoning.

Heavy, flat-bottomed pans are designed to heat food evenly, but woks use a very different system. Their curved shape means that the bottom section nearest the burner gets the hottest, and the thin metal ensures it heats up very quickly. Meanwhile, the outer edges remain relatively cool, allowing the chef to cook ingredients at different temperatures in the same pan.

The curved shape of the wok also makes it easy to toss the food with one quick and easy motion, giving the chef even more control over how the food is cooked. Just before it starts to burn, they can send the ingredients flying through the air where they continue to cook in the steam and heat above the wok. Meanwhile, this gives the wok itself a chance to cool slightly. Tossing the food can also splash droplets of oil onto the burner, creating large flames that help singe the food and contribute to the smoky taste of a 'wok hei' meal.

Wok seasoning

Most professional woks are made of carbon steel or cast iron and do not come with a non-stick coating. Before using a new wok, chefs often create their own protective layer, by covering the inside of the pan with oil and placing it over a very high heat. The heat causes the oil to polymerise and stick to the surface, creating a hard, non-stick film. With more use, the coating will darken and contribute to the taste. This process is known as 'wok seasoning'. Some chefs may also throw in some herbs and spices with the oil to strengthen the 'wok hei' taste.

Seasoning a wok makes it non-stick and enhances the taste of the food

© WIKI

In the wok

Find out how woks help give Chinese food its distinctive taste

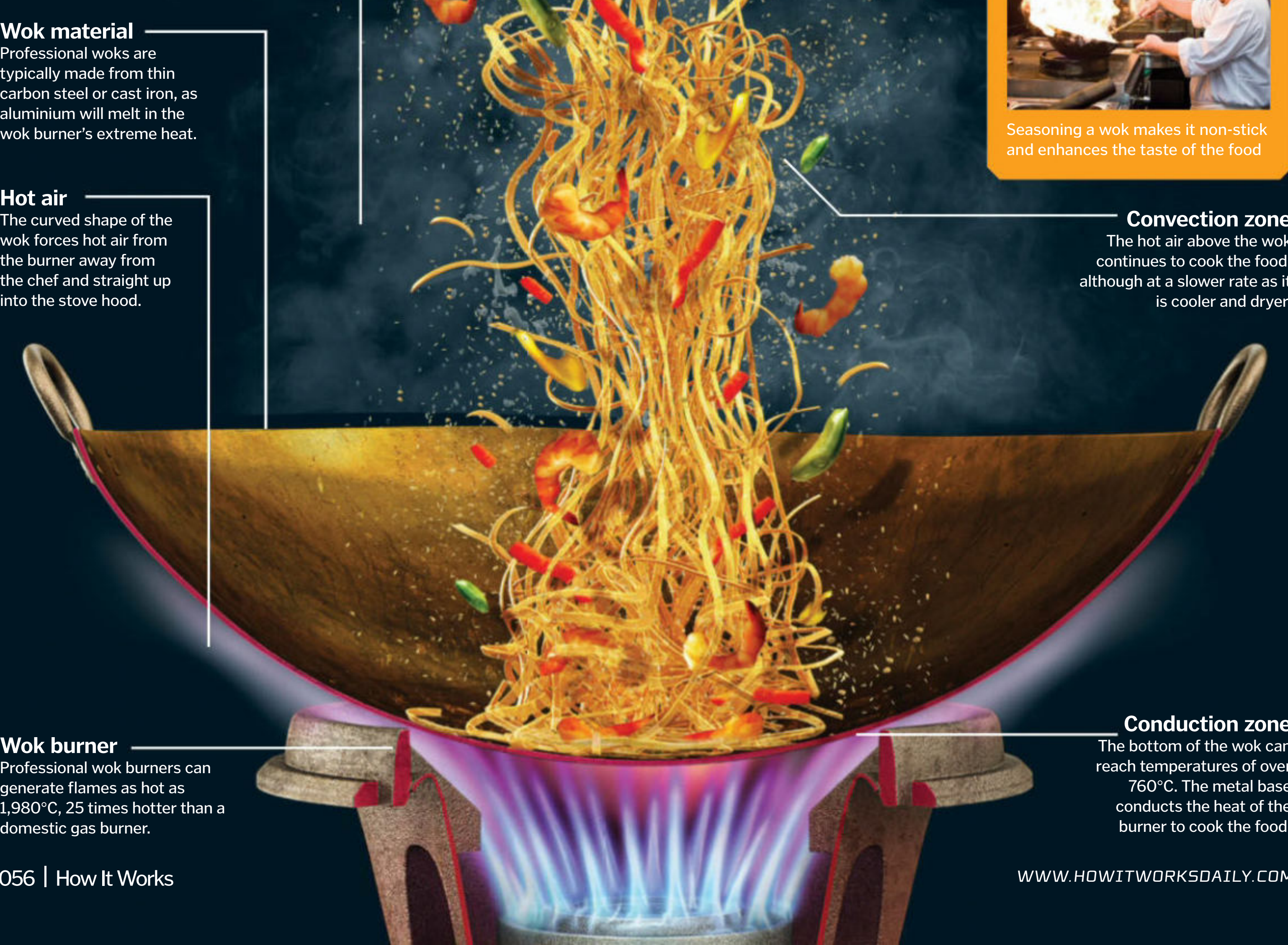


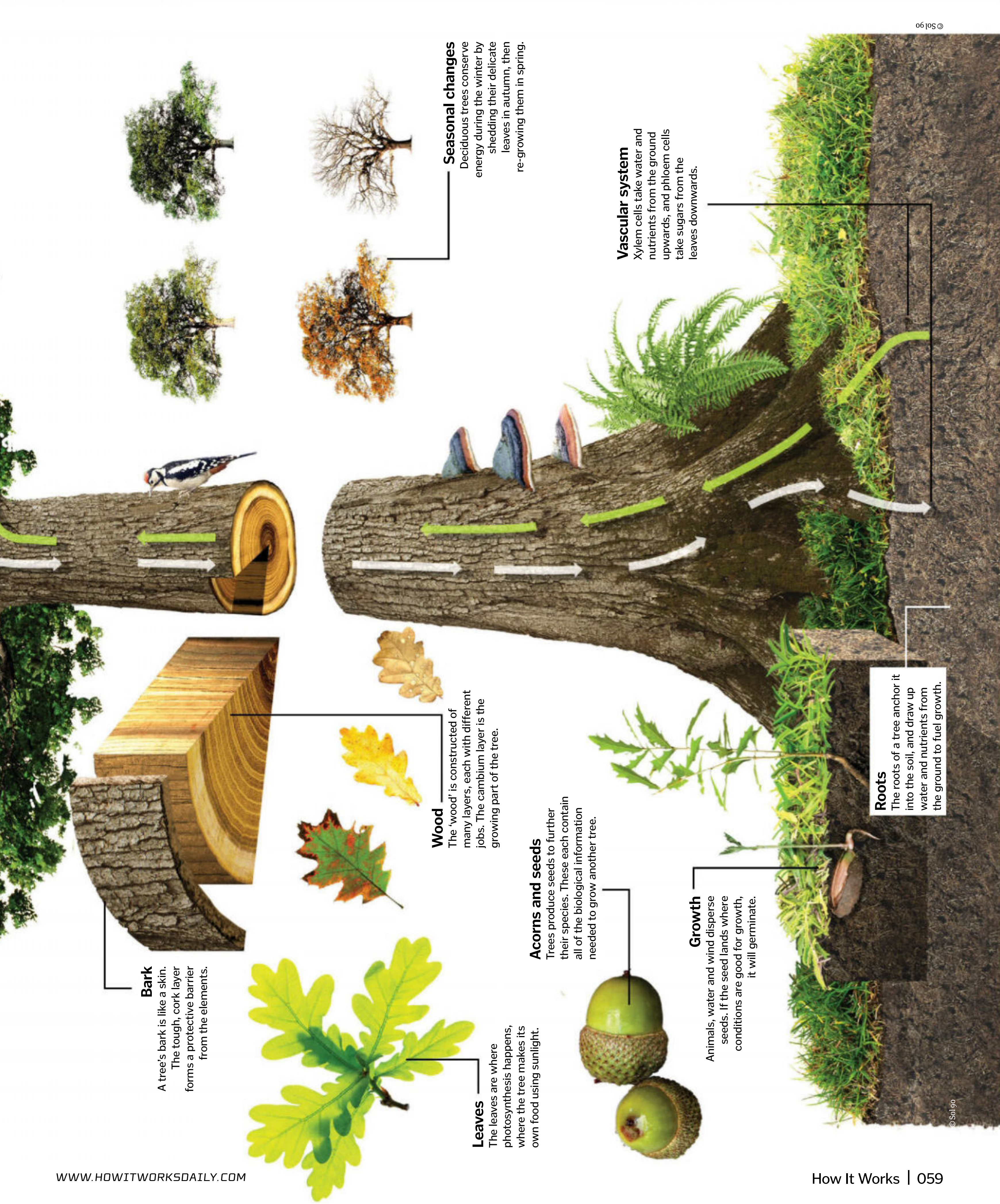
Illustration by Nicholas Forder


There are around 600 species of oak tree, found across the Northern Hemisphere

The life of trees

From seed to forest giant, discover how trees grow and why you can't live without them

When you look at a tiny acorn on the forest floor, it's difficult to imagine just how much potential that little seed contains. If it germinates, after around 50 years it will have grown into a towering oak tree, with the capacity to outlast generations of humans. And that's just one tiny acorn. Scientists have estimated that there are around 3 trillion trees on our planet, belonging to around 100,000 different species. Each of these trees contributes to regulating our climate and producing air for us to breathe, as well as many more important roles that may surprise you.



Seasonal changes
Deciduous trees conserve energy during the winter by shedding their delicate leaves in autumn, then re-growing them in spring.
Vascular system
Xylem cells take water and nutrients from the ground upwards, and phloem cells take sugars from the leaves downwards.
Roots
The roots of a tree anchor it into the soil, and draw up water and nutrients from the ground to fuel growth.
Wood
The 'wood' is constructed of many layers, each with different jobs. The cambium layer is the growing part of the tree.
Acorns and seeds
Trees produce seeds to further their species. These each contain all of the biological information needed to grow another tree.
Growth
Animals, water and wind disperse seeds. If the seed lands where conditions are good for growth, it will germinate.
Bark
A tree's bark is like a skin. The tough, cork layer forms a protective barrier from the elements.
Leaves
The leaves are where photosynthesis happens, where the tree makes its own food using sunlight.
© Sol 90
© Sol 90

Woodland wildlife

Forests are home to more wildlife than any other landscape

From leaves to bark and everything in between, every inch of woodland is useful to one critter or another. Large populations of trees create many varied habitats, from pine forests to wet woodlands, each with different ecological properties and a unique wildlife population.

In summer, when a tree's leaves are in full bloom, the dense foliage of the woodland canopy absorbs the Sun's energy, providing shade and regulating the woodland's climate. Similarly, in the winter months, the dense network of leaves and branches are an effective barrier against pouring rain and howling wind, sheltering the animals within.

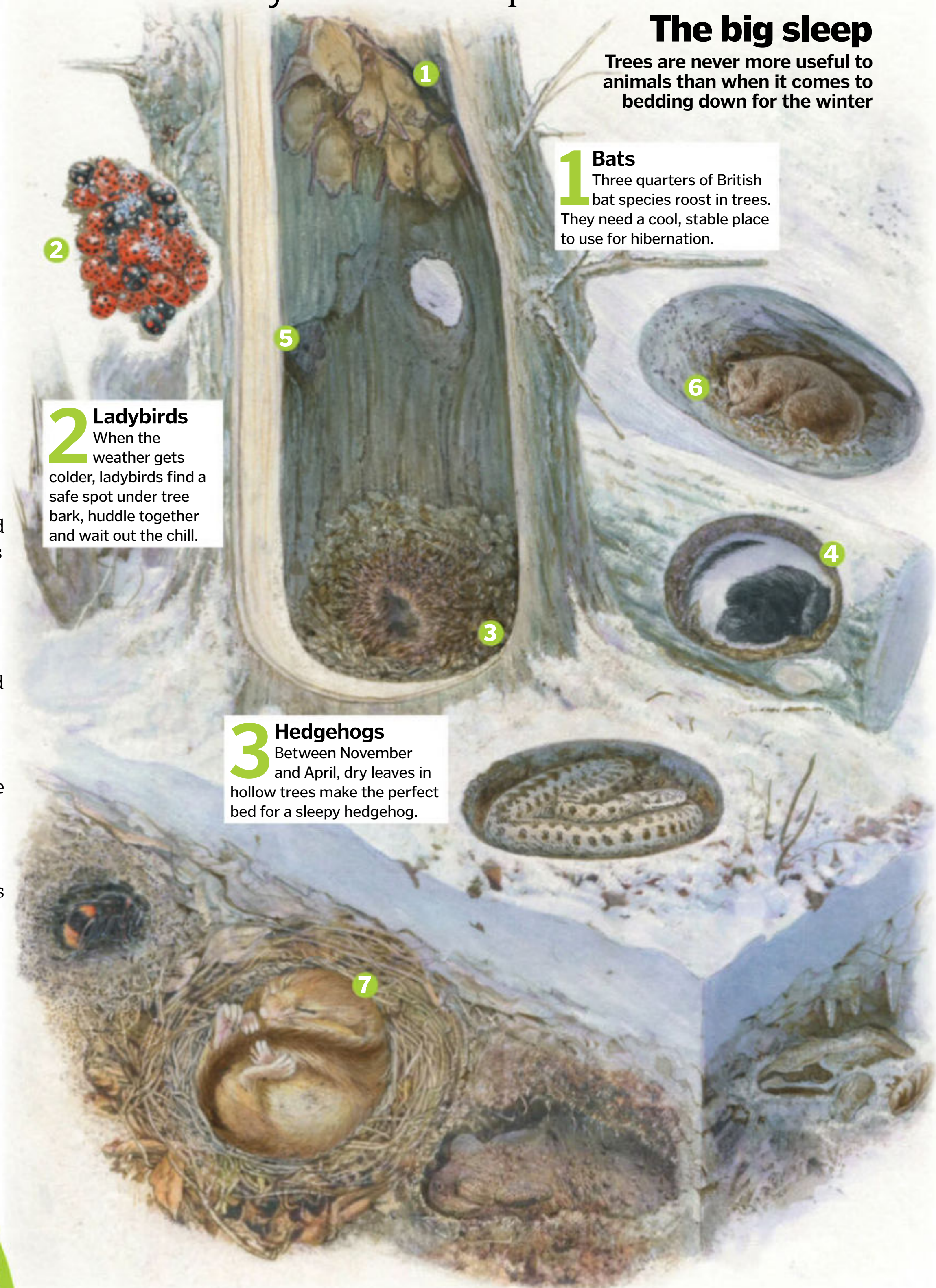
Green leaves, buds, fruit and bark provide food for many animals, such as squirrels, deer and birds. A tree's branches make handy perches for feasting upon, or a perfect vantage point to lie in wait for prey. Refuge is also found high up in the branches, safe from the clutches of forest-floor predators.

Lines of trees can also connect different ecosystems together, providing green corridors for animals to cross between different habitats, maintaining the flow of food and nutrients throughout the countryside.

The tree's structure itself provides plenty of nooks and crannies for wildlife to hide in. Birds build nests on branches or hollow out the bark, insects live on the underside of leaves, bats and dormice seek out tree cavities for refuge and burrowing critters weave throughout the roots. Even when a tree dies it's useful; leaf litter creates a rich mix of nutrients on the forest floor for scavengers, and dead wood can support countless plants, insects and fungal species.

The big sleep

Trees are never more useful to animals than when it comes to bedding down for the winter



1 Bats
Three quarters of British bat species roost in trees. They need a cool, stable place to use for hibernation.

2 Ladybirds
When the weather gets colder, ladybirds find a safe spot under tree bark, huddle together and wait out the chill.

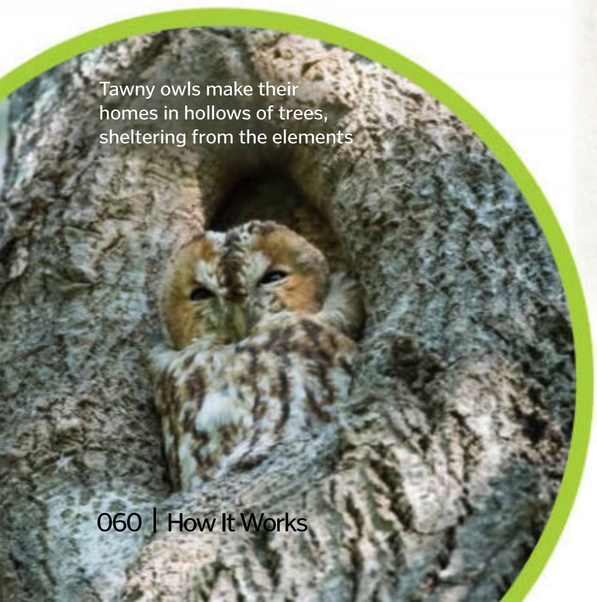
3 Hedgehogs
Between November and April, dry leaves in hollow trees make the perfect bed for a sleepy hedgehog.

4 Badgers
Badgers live in tunnel networks known as setts. Tree roots make these underground dens more stable.

5 Moths
Depending on the time of year, moths and caterpillars can use branches for hibernating in large groups.

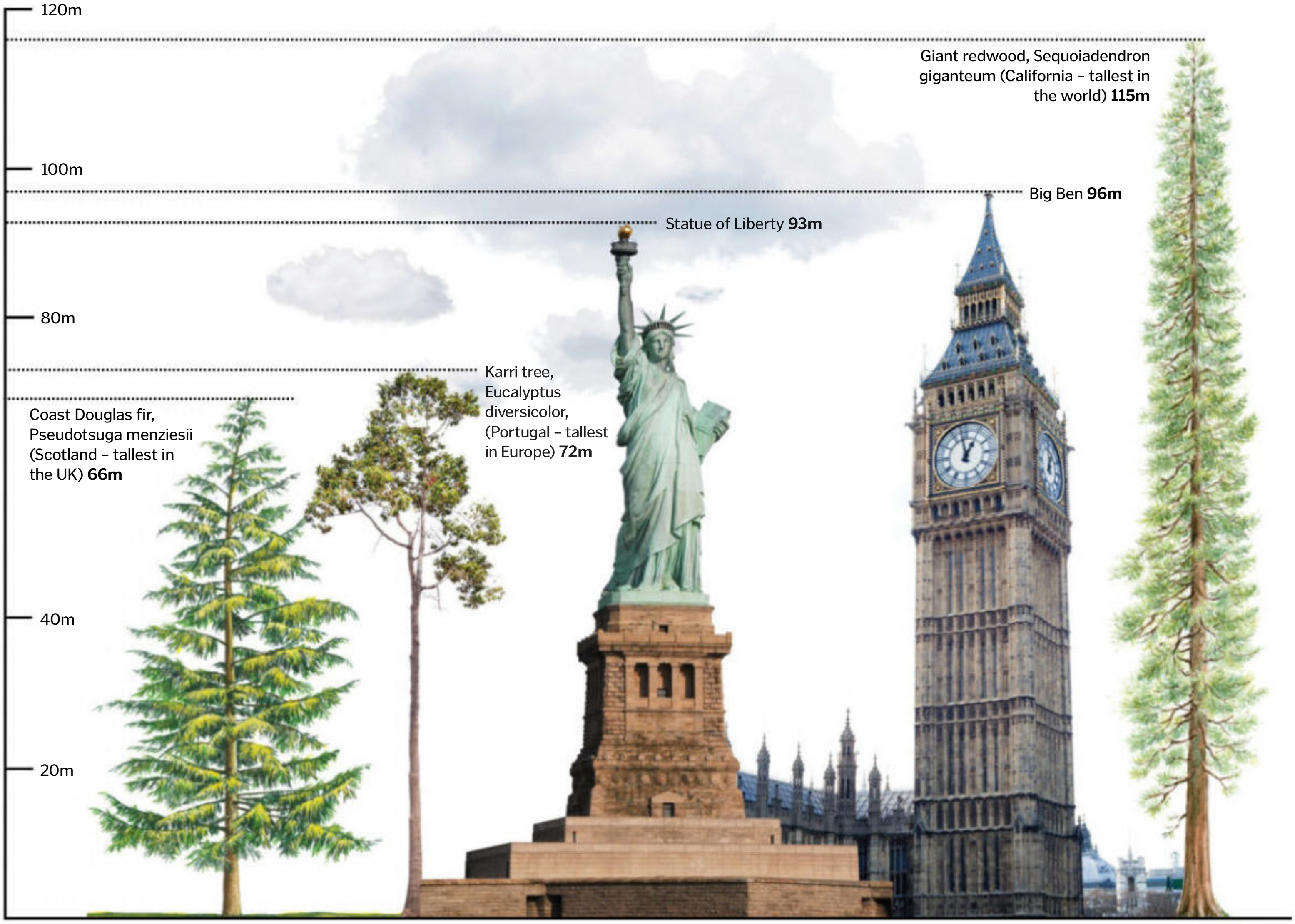
6 Bears
These great beasts will collect leaves, branches and brushes of trees to create a warm bed to curl up in.

7 Dormice
Found living in deciduous woodland, dormice make cosy nests to keep out of the winter chill.



Tawny owls make their homes in hollows of trees, sheltering from the elements

The world's tallest trees



The importance of trees

Giant redwoods thrive in the warm, humid climate of northern California

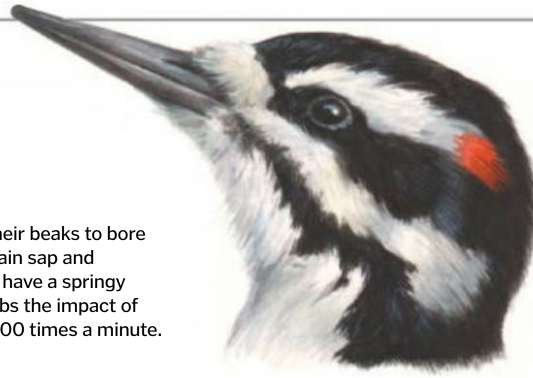
The forest does far more for us humans than provide beautiful walks and firewood

Trees are the lungs of our planet. As a key part of the carbon cycle, when trees photosynthesise to make their own food, they take in carbon dioxide and convert it to release oxygen, storing the rest of the carbon that gets decomposed into the soil when the tree dies. When a whole forest does this, the intake of CO_2 is huge. With rising CO_2 levels in our atmosphere being an important factor in climate change, the work of trees becomes all the more prominent. It's estimated that our planet's trees absorb up to 40 per cent of the carbon dioxide created by humans each year.

When the trees are cut down, this carbon storage is removed, but so is the tree's ability to stabilise the earth and take up water. Deforestation creates a landscape where water flows uninterrupted, taking valuable, nutrient-laden surface soil with it. This leaves land barren and infertile – a disaster for agriculture and those who depend on farming for their livelihood. Flash floods wreak havoc and threaten human life, and have been directly linked to the removal of trees across the world. Downstream, the soil that has been removed by floods is deposited as the flow peters out, and can clog up dams and create further issues.

Bird beaks

You can learn a lot about what a bird eats from the shape of its beak



Chiselling

Woodpeckers use their beaks to bore into tree bark to obtain sap and insects. Their beaks have a springy structure that absorbs the impact of hitting a tree trunk 100 times a minute.

Pursuit fishing

This relatively flat bill helps aquatic birds to catch fish when they dive underwater. A cormorant is good at using its beak this way, piercing fish with the hooked upper bill.

Dip netting

Pelicans use their large, pouch-like bill to strain excess water once they have caught a mouthful of fish. It also attracts potential mates and scares away predators.

Filter feeding

Flamingos feed upside down using their upper bill as a scoop. Their fleshy tongues act like a pump to filter water, leaving behind the tiny marine life that these birds feed on.

Fruit eating

Toucans have an oversized beak for reaching hanging fruit. It also helps to keep them cool by allowing heat to escape, using a network of blood vessels to control blood flow.

Nectar feeding

These needle-like beaks can probe flowers, providing a sheath for the bird's tongue. Nectar is drawn up by capillary action, similar to a paper towel absorbing water.

Grain eating

Finches are equipped with short, stout, cone-shaped bills. They use their upper and lower mandibles like a nutcracker, to break open tough seed cases and grain.

Surface skimming

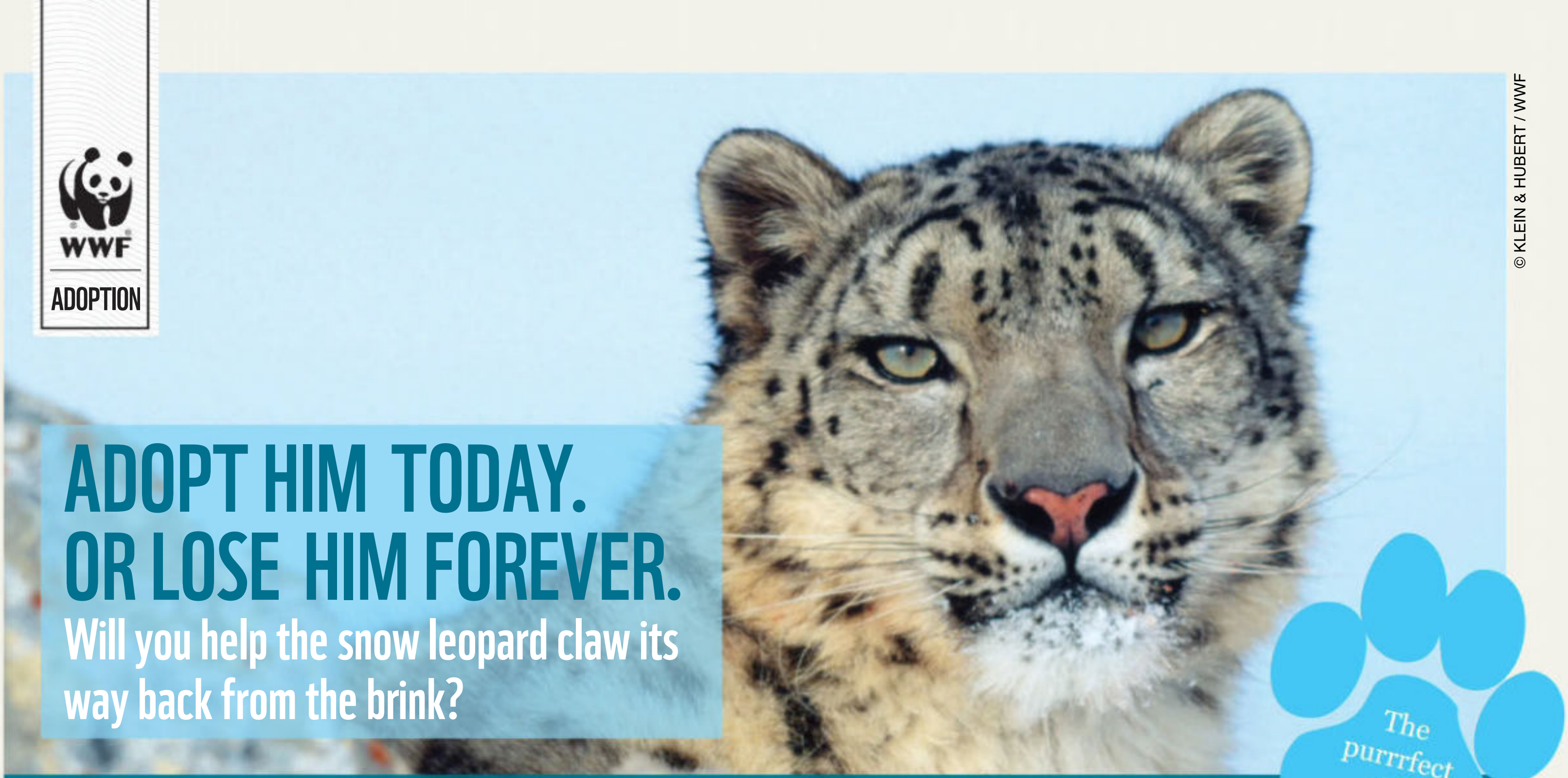
Skimmers such as herons and phalaropes have blade-like beaks. They feed by lowering the longer, lower jaw into the water and snapping it shut once they touch a small fish.

Raptorial

Hawks, eagles and other carnivorous birds use their sharp, hooked beaks to catch and kill their prey, ripping into the skull or neck and tearing the body into bite-sized pieces.

Scavenging

Scavengers such as vultures have powerful, hooked beaks. Like built-in knives, these allow birds to tear through the flesh of carcasses with ease.



ADOPT HIM TODAY. OR LOSE HIM FOREVER.

Will you help the snow leopard claw its way back from the brink?

Snow leopards have survived in the Himalayas for thousands of years. But right now, there are as few as 300 left in Nepal. The harsh reality is that they're being hunted by poachers for their bones and precious fur – and they urgently need your help if they are to live on.

By adopting a snow leopard today, you'll help protect this endangered big cat for future generations.

Your present. Their future.
For as little as £3 a month, you or your loved one will receive an adoption pack, an adorable cuddly toy and regular updates from people on the ground working tirelessly to help save the beautiful snow leopard.

What's more, you'll have the satisfaction of knowing you're helping us to train and equip courageous anti-poaching rangers. And you'll discover what it takes – and how it feels – to help save a species.


a gorgeous snow leopard toy

\+


an adoption pack

\+


regular updates from the field

= *from just* £3 a month

Adopt a snow leopard today by filling in the form below, visiting wwfsnowleopard.com or calling 0845 200 2392

Yes, I would like to adopt a snow leopard today

Please indicate how much you would like to give each month

I would like to give ☐ £3 ☐ £5 ☐ £7 ☐ £10

My choice £ ______ each month (min. £3)

Purchaser details

Title:__________ Initial:__________ Surname: ______________________

Address:____

______________________________ Postcode: ______________

Tel no: ______________________ Date of birth: ______________

Email:* ____

*Please supply if you would like to receive emails from WWF (you can unsubscribe at any time)

Gift recipient details (if applicable)

☐ Tick this box if your adoption is a gift, then complete the details of the recipient below

Title:__________ Initial:__________ Surname: ______________________

Address:____

______________________________ Postcode: ______________

Gift recipient's date of birth: ______________________

Would you like us to send the adoption pack directly to the recipient? ☐ Yes ☐ No

We'd like to keep you up to date with our projects and activities by post and telephone. If you'd prefer not to receive information in this way you can email us at supportercare@wwf.org.uk or call us on 01483 426333.

DIRECT DEBIT – WWF-UK

DIRECT Debit

Instruction to your Bank or Building Society to pay Direct Debits.

Service User Number 9 9 1 4 7 3

1. Name and full postal address of your Bank or Building Society Branch

To the manager of:______________________________ Bank or Building Society

Address:____

______________________________ Postcode: ______________

2. Name(s) of account holder(s)

3. Branch sort code ☐☐-☐☐-☐☐

4. Bank or Building Society account number ☐☐☐☐☐☐☐☐

5. WWF-UK Reference Number (Office use only)

6. Instructions to your Bank or Building Society

Please pay WWF- UK Direct Debits from the account detailed on the instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with WWF-UK and, if so, details will be passed electronically to my Bank/Building Society. Banks and Building Societies may not accept Direct Debit Instruction for some types of account.

Signature(s): Date:

Your money will support our work to help save the snow leopard as well as other vital conservation projects.

Freepost RTSK-ZCLS-EEUZ, WWF-UK, York House, Wetherby Road, Long Marston, York, YO26 7NH

FRSB give with confidence

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How cenotes form

Dip your toe into a world where geology and ancient history go hand in hand

Found on Mexico's Yucatán peninsula, a cenote (pronounced 'say-no-tay') is effectively a really pretty sinkhole. These colossal underground caverns are filled with deep, crystal-clear water and are used as both swimming and diving spots for tourists and scuba enthusiasts, not to mention being sites of incredible archaeological and cultural significance for the Yucatán's locals.

The Yucatán peninsula is formed of limestone and was once a coral reef, exposed just above sea level during the last ice age. The peninsula doesn't have many rivers or steams above ground, but below the surface flow the three longest underground water systems in the world. These essential waters have helped civilisation thrive on the Yucatán for thousands of years.

Fractures in the limestone bedrock form the beginnings of a cenote. Rain and groundwater, which can be slightly acidic, filter through these cracks. This acidic liquid then slowly dissolves the soft limestone, meaning the cracks gradually get larger and larger. Due to the low-lying land, over millennia more water filters through the rock and a cave eventually forms. This cave is then filled up with the subterranean water that flows beneath the ground.

Over time, the water wears the limestone away to create great, cavernous chambers. The ceilings of these chambers are the weakest part, and when they eventually cave in the structure is then known as a cenote. From above, sunlight streams in and tree roots crack through the rock, reaching downwards for the moisture below.

There are over 6,000 cenotes in the Yucatán peninsula, although only 2,400 are studied and registered. With their giant, cathedral-like domes filled with dizzyingly deep and clear water, it's quite easy to see why ancient civilisations considered these rock formations to be entrances to other worlds and feared what lay within.

The world's longest underground river

Beneath the surface, Mexico's Yucatán peninsula is a labyrinth of limestone caves and underground waterways. The title for 'longest underground river' was previously claimed by the Puerto Princesa Subterranean River in the Philippines, which runs for 8.2 kilometres through limestone caves before joining the South China Sea.

Now, thanks to four years of exploration by British and German divers, the Sac Actun (meaning 'white cave') river system has been discovered to run for 153 kilometres through the Yucatán's limestone maze, earning it the title of the world's longest running underground river.

The discovery occurred when the divers found a link between the region's two longest cave systems, the Sac Actun and the Nohoch Nah Chich (meaning 'giant birdcage'). The entire network, which is now collectively known as Sac Actun (including the dry caves without the flow of the river), has a total surveyed length of 319 kilometres, making it also the second longest cave system in the world, behind the 644-kilometre Mammoth Cave system in Kentucky.

A cave diver in Chac Mool Cenote, Playa del Carmen, in the Yucatán Peninsula, Mexico

"The water wears the limestone away to create great cavernous chambers"

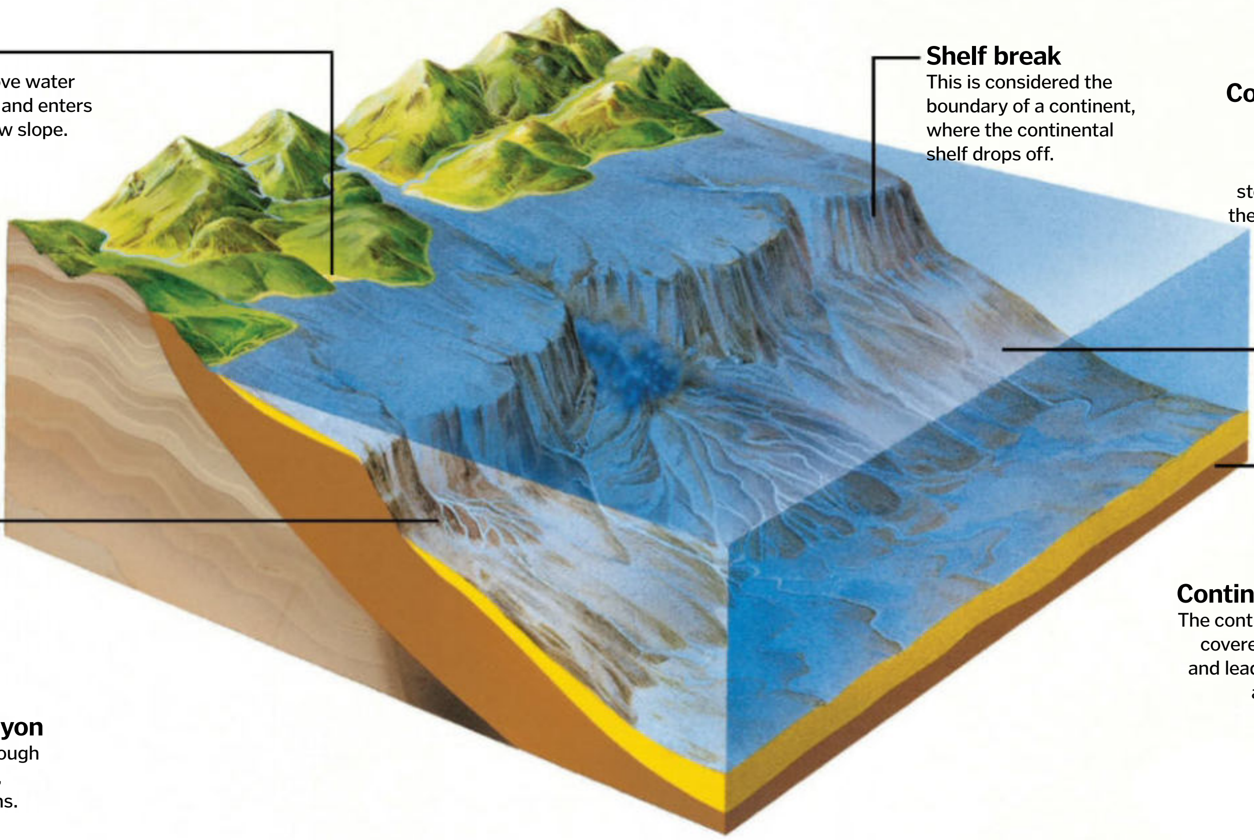
The continental shelf

Ever wondered what happens to the ground you stand on when it reaches the ocean?

Earth's crust is made up of tectonic plates, seven of which protrude far above sea level to form the world's continents. Each has a boundary known as the continental shelf. As the continental landmass meets the sea at the coast, it slopes gradually into the ocean until it suddenly drops off – this is called the shelf break. It's an abrupt, steep, underwater cliff that leads onto a much steeper gradient known as the continental slope. Beyond this lies the deep ocean floor.

Most continental shelves extend about 65 kilometres from the coast, to average depths of 100 to 200 metres. The shelf is mostly made up of thick layers of mud and silt lying on top of the bedrock that has run off from the land over millennia. Sometimes there are deep underwater canyons that cut through the continental slope, creating very deep, dark and murky environments.

Continental shelves make up about eight per cent of the total area covered by oceans, and due to their relatively shallow depths, they are teeming with plant and animal life.



Landmass
The body of land above water forms the continent, and enters the ocean at a shallow slope.

Shelf break
This is considered the boundary of a continent, where the continental shelf drops off.

Continental slope
Here the sea floor slopes steeply toward the deep ocean.

Continental rise
The continental rise is covered in thick silt and leads to the vast abyssal plain.

Submarine canyon
Deep gouges cut through the continental shelf, forming huge canyons.

The secrets of woodlice

There's far more to these little critters than meets the eye

The next time you move something in the garden and see a woodlouse scuttling out from underneath, remember that these little guys are in fact isopod crustaceans! They're more closely related to crabs and lobsters than ants and spiders. Although they're landlubbers, one trait woodlice share with their aquatic cousins is that they use gills to breathe.

They like to live in moist, dark places where there's plenty of decaying material to eat. Their bodies are made up of armoured segments of an exoskeleton that allow them to roll up into balls when threatened (hence the nickname 'pill bug'). As they grow, woodlice need to shed their skin. This happens in two separate stages; the back sheds first, followed by the front, which is why a woodlouse may sport two different colours.

Shuffling on 14 legs, woodlice have two 'uropods' at the back of their bodies. These are for navigation, and some species use them to secrete defensive substances. Uropods are also used for drinking; the louse sucks up water through the tubes into its anus. Any waste moisture is excreted as ammonia gas through pores in the exoskeleton, as woodlice don't ever pee!

Woodlice are so tolerant to heavy metals that they can be used as pollution bioindicators

LIVING ON THE MOON

How we could turn craters into colonies for human life

The Moon is our closest neighbour, but only 12 people have ever set foot on its surface. Since 1972, the only visitors have been robots, orbiters and probes. For a long time there was little interest in going back, but at just three days journey away from Earth, the Moon is an obvious target for further investigation. With more countries establishing their own space programmes, and an increasing number of private companies entering the field, interest in the Moon is growing once again.

The environment on the Moon's surface is hazardous, but if we can find a way to construct a base we would gain access to a wealth of off-world resources. It is a prime location for telescopes and communications equipment, and its unique environment could hold clues to the history of the Solar System. The Moon's potential has been recognised by organisations across the world, and there are now several exploratory missions in development. At the moment, these are focused around finding out more about the Moon's potential, but over the next few decades, manned missions and even base construction could be on the agenda.

Russia's Roscosmos are planning a series of Luna-Glob missions as a starting point for establishing a robotic base, and in collaboration with the European Space Agency, they are hoping to scope out the Moon's south pole in 2019 and 2020. The China National Space Administration are developing a series of Chang'e probes to collect lunar samples in preparation for future mining missions, and they are building a shuttle capable of lifting human astronauts to the Moon. What's more, in 2007, Google launched the Lunar XPRIZE, encouraging private companies to land rovers on the surface by 2017. Even NASA, who has chosen to focus their resources on manned missions to asteroids and to Mars, are developing a probe to map the water deposits on the lunar south pole.

At the moment, we are just taking our first tentative steps towards further exploration of the Moon, but in the future a science fiction-style base on the surface could become a reality. We explore what such a lunar outpost might look like, and what hazards and challenges could get in the way.

Why the Moon?

With preparations already underway for manned missions to Mars, some might question the logic behind a return to the Moon, but a lunar outpost could bring several advantages. A trip to the Moon and back could be completed in under a week, and the surface is rich in resources. Lunar dust contains hydrogen, oxygen, iron and other metals, and if these resources could be mined, it could provide a close off-world source of water and building materials.

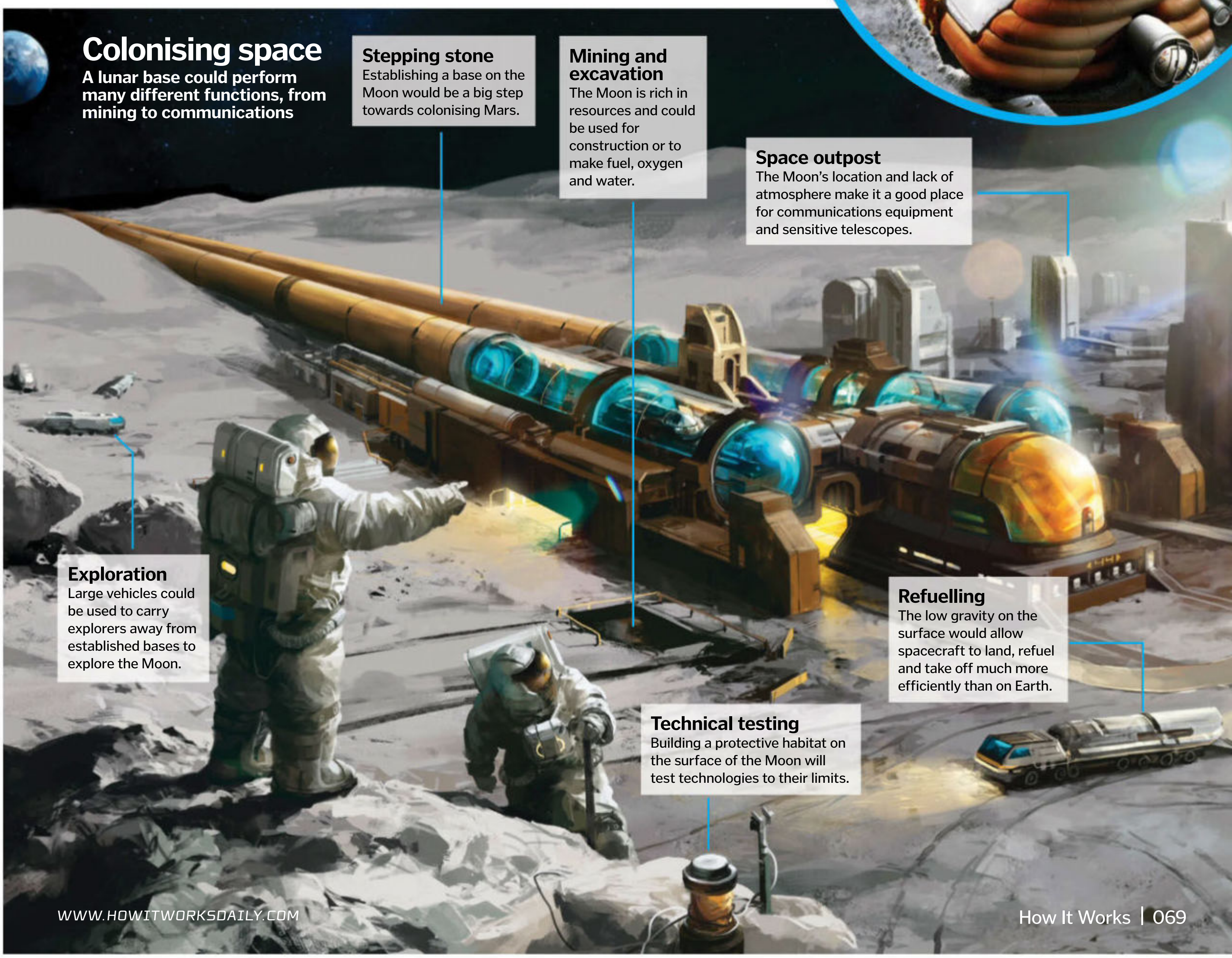
The far side of the Moon is shielded from the noise of Earth's communications, providing a quiet vantage point for looking out into the universe, and the near side has a constant view of the surface of our planet, making it an ideal place to set up monitoring stations. Navigational support could also be provided for a variety of operations, from search and rescue on Earth to deep space exploration.

A base on the Moon would also allow us to look closer at its geology, which in turn would help us uncover more about its history and the evolution of the Solar System. Experiments could be conducted, and materials and equipment could be tested, away from the familiar conditions on Earth.

Lunar holidays

With space tourism barely in its infancy, it might seem a bit premature to consider the idea of holidaying on the Moon, but if humanity were to establish a base up there, visitors would almost be inevitable. The company Space Adventures has already sold two $150 million tickets for a trip to visit the Moon in 2018, and more private organisations are looking to set up their own tours. Rules set out in the 1967 Outer Space Treaty state that the Moon cannot be claimed by any country, even if they have set up a base there. However, laws regarding the exploitation of the Moon and its resources for commercial gain have not yet been fully established.

A base on the Moon could pave the way for a new kind of holiday



How to build a base

The Moon has little atmosphere and none of the protective shielding that we enjoy here on Earth; as a result, the surface is hostile. It is pummelled by solar winds, scorched by radiation, and chunks of rock regularly fall from the sky. The ground is coated in the shattered remains of ancient asteroid impacts, forming a thick layer of sticky dust, and with no atmosphere or weather to wear the particles down, the grains are razor sharp. A successful base would need protection against all of these threats, and, for people to stay there long-term, it would also require a steady supply of food, water, oxygen, power, shelter and rocket fuel.

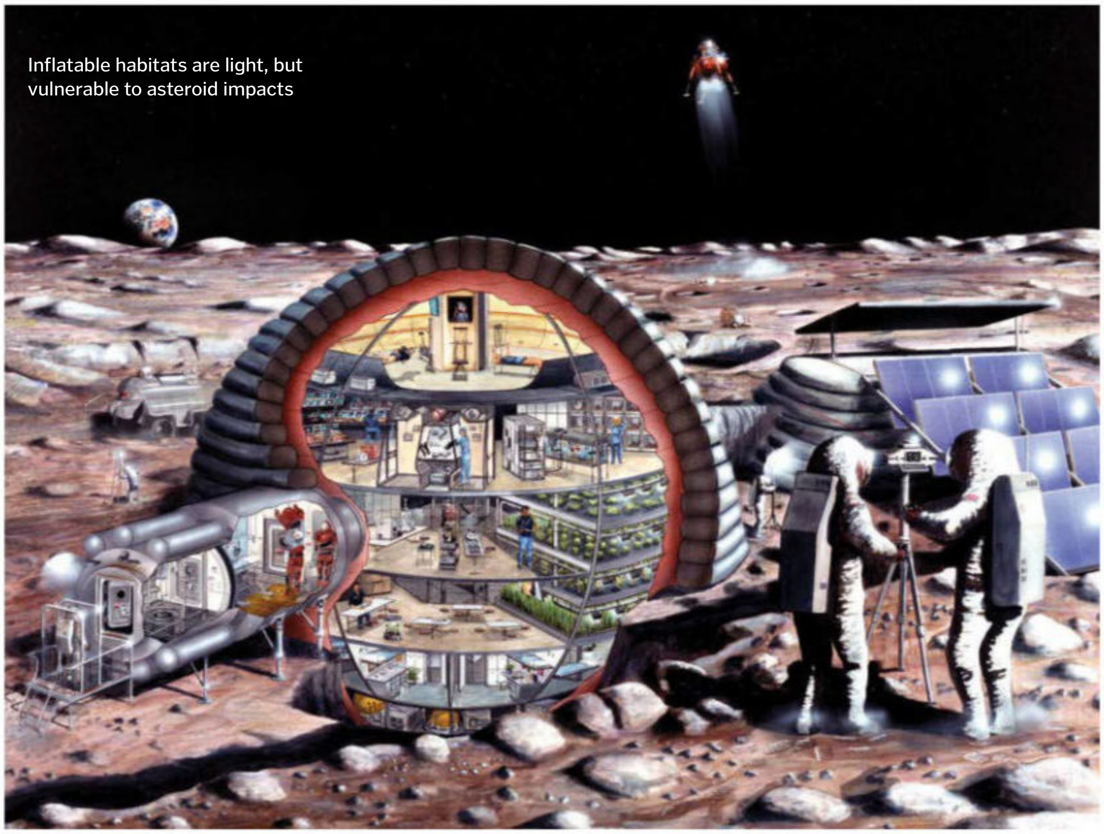
One of the most popular concepts for a lunar base is inflatable housing – lightweight and easily assembled by pressurising from the inside. With the airlock from the landing capsule used as a door, these structures could provide a quick and simple solution to setting up a base. However, a puncture could prove catastrophic, so the pods would need to be shielded in underground chambers or beneath piles of Moon dust.

Flat-packed panels could also be shipped in from Earth to build sturdier dome or hangar structures, but it would be much more fuel-efficient to use building materials found on the surface of the Moon. When heated, lunar dust can be transformed into a tough solid that could be used to construct buildings and roads, and 3D printers could one day be used to make structures from the regolith.

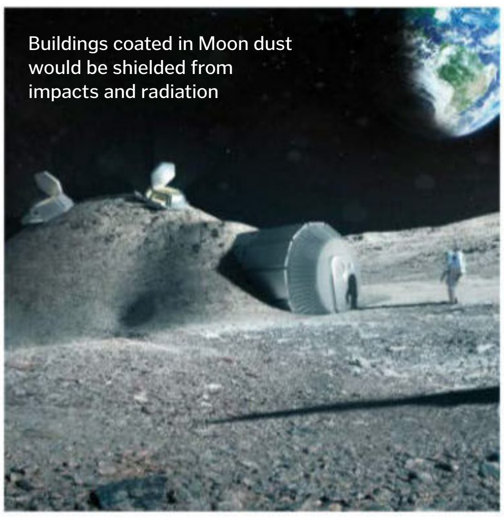
In the right location, solar panels could provide renewable power for the base, and, if plants are able to grow on the Moon, it could one day be possible to set up a semi-sustainable farming and composting system. Then, if water, oxygen and hydrogen (rocket fuel) could be extracted from lunar dust, a base might even be able to become self-sufficient.

Unfortunately, there are still major challenges to be overcome before we reach this stage, not least the devastating effects of lunar dust. The dust seems to find its way inside even tightly sealed spaces, causing rapid damage to equipment. There are some ideas to get around this, including cable cars or covered transport tubes to minimise the disturbance on the surface, and clean rooms and air locks to keep inside spaces dust-free.

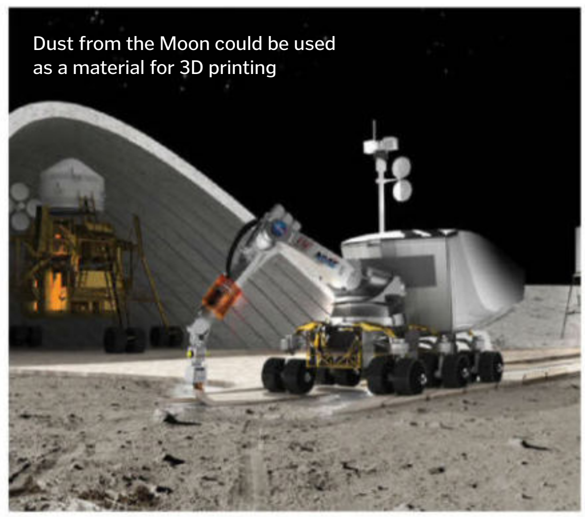
> "Solar panels could provide renewable power for the base"



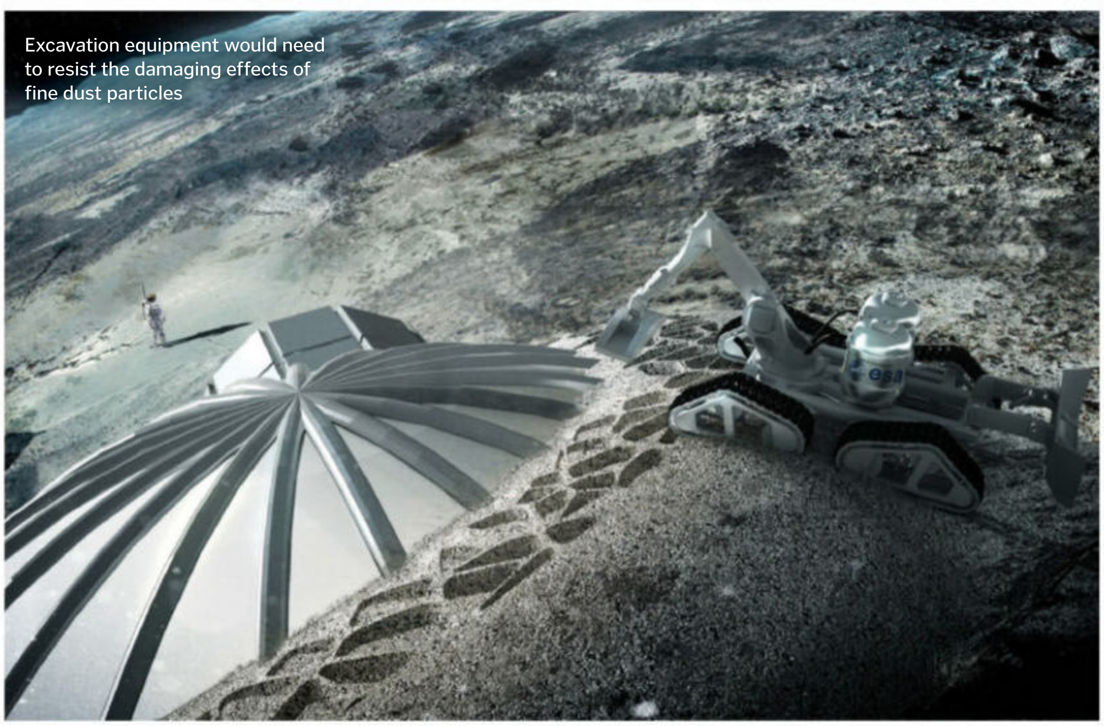
Inflatable habitats are light, but vulnerable to asteroid impacts



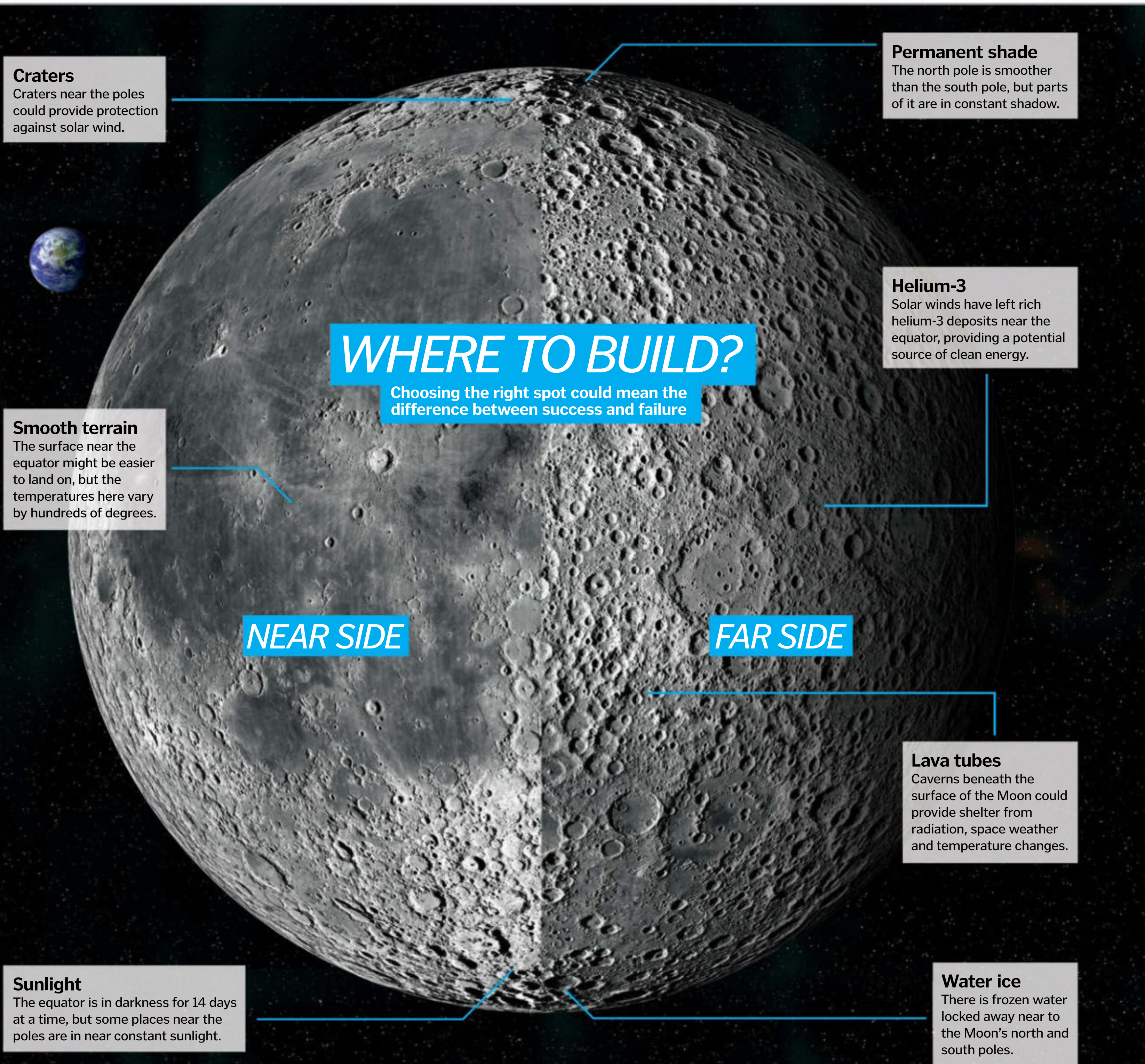
Buildings coated in Moon dust would be shielded from impacts and radiation



Dust from the Moon could be used as a material for 3D printing



Excavation equipment would need to resist the damaging effects of fine dust particles



Location, location, location

The Apollo missions landed close to the Moon's equator, where the surface is smooth and entering orbit is easy, but these regions have serious problems with temperature control. The Moon turns on its axis once every 28 Earth days, so daytime at the equator lasts for two weeks, and temperatures climb to more than 100 degrees Celsius. For the other two weeks, the same spot is plunged into total darkness and the surface cools to 150 degrees below freezing.

These wide fluctuations could pose real problems for buildings and equipment, and with sunlight absent for days at a time, solar power would be intermittent. Facing head on to the Sun and with little in the way of atmosphere, the equator is also blasted by radiation and solar winds.

At the poles, night and day are less dramatic. The surface is rougher, but certain areas receive sunlight for most of the year, and the temperature remains more stable at around zero degrees Celsius. There is also water ice trapped at the poles, which could provide gases, fluids and even rocket fuel.

One promising location is Shackleton Crater, which is found at the Moon's southern pole. It receives sunlight for around 80 per cent of the year, which could provide a near constant source of electricity from solar panels. Building a base near the equator would be more challenging, but underground habitats could provide enough protection in more exposed locations. Lava tubes like the Marius Hills pit could offer ready-made shelter from temperature fluctuations, solar wind, radiation and surface dust.

WHAT WOULD A LUNAR COLONY LOOK LIKE?

The Moon is not a safe place for humans; the base will be essential for survival

Inflatable habitats
Building materials are heavy, so one option is to use inflatables. These would need to be protected from impacts.

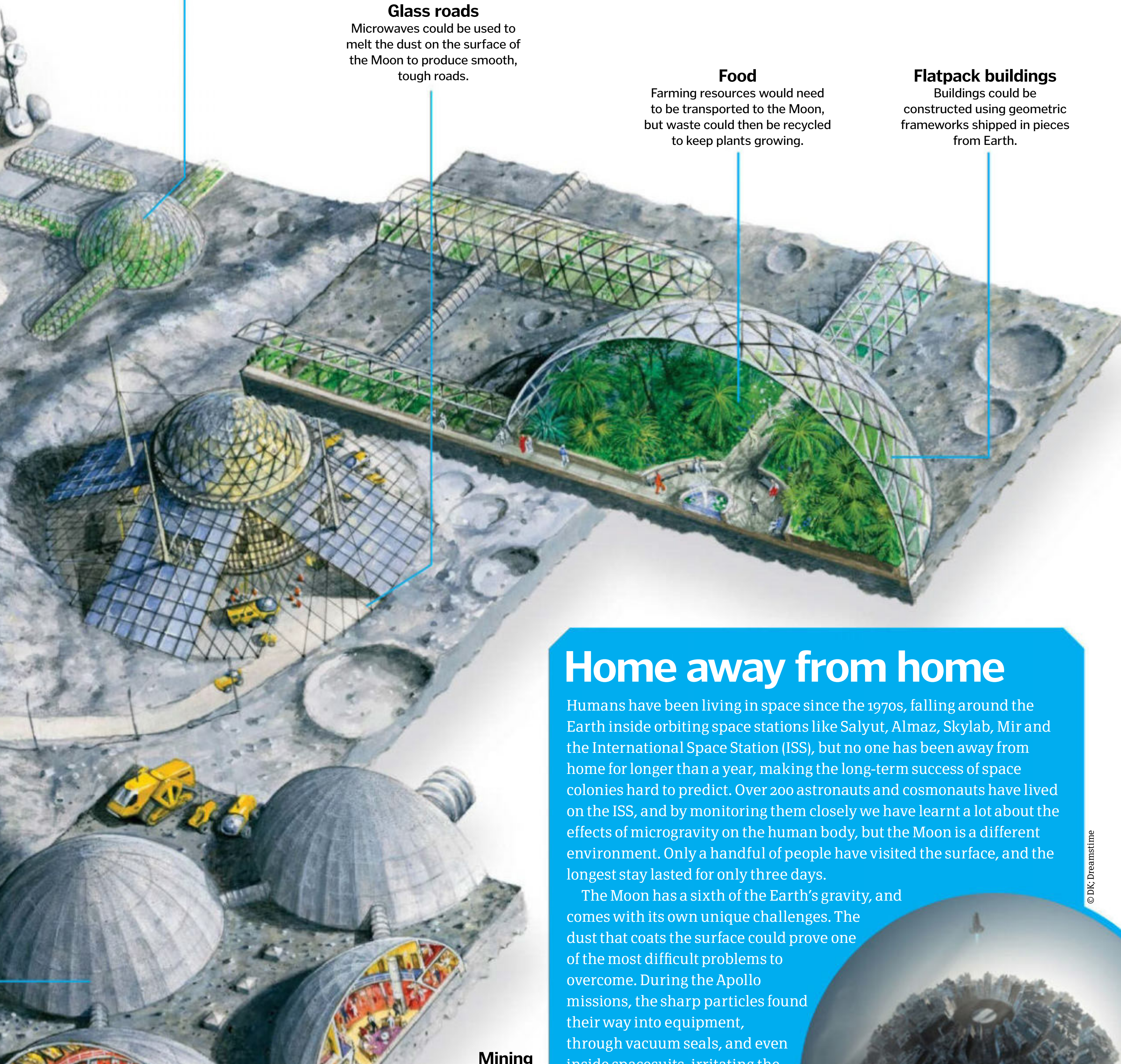
Water supply
Water could be extracted from lunar dust by heating it with hydrogen gas.

Launch and landing
The gravity on the Moon is low, so launching and landing spacecraft requires much less fuel than it does on Earth.

Telescopes and equipment
Away from the interference of Earth's atmosphere, a lunar base could house powerful telescopes.

Radiation shielding
Buildings would need to be protected from radiation. A popular idea is to bury them under layers of moon dust.

"Only a handful of people have visited the Moon's surface, and the longest stay lasted three days"



Home away from home

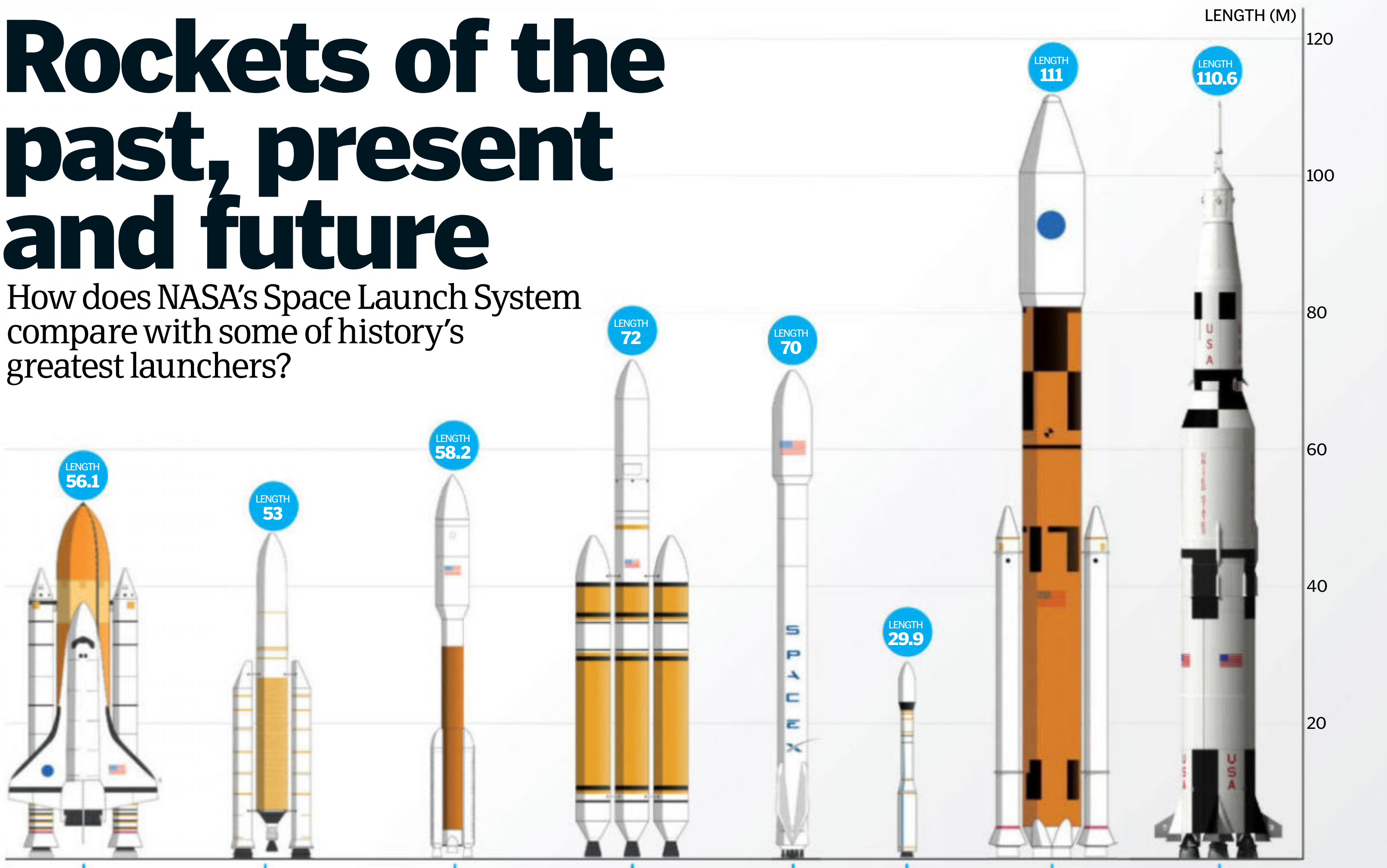
Humans have been living in space since the 1970s, falling around the Earth inside orbiting space stations like Salyut, Almaz, Skylab, Mir and the International Space Station (ISS), but no one has been away from home for longer than a year, making the long-term success of space colonies hard to predict. Over 200 astronauts and cosmonauts have lived on the ISS, and by monitoring them closely we have learnt a lot about the effects of microgravity on the human body, but the Moon is a different environment. Only a handful of people have visited the surface, and the longest stay lasted for only three days.

The Moon has a sixth of the Earth's gravity, and comes with its own unique challenges. The dust that coats the surface could prove one of the most difficult problems to overcome. During the Apollo missions, the sharp particles found their way into equipment, through vacuum seals, and even inside spacesuits, irritating the eyes and lungs of the astronauts.

Permanent settlements on the Moon will only be possible with proper protection

Rockets of the past, present and future

How does NASA's Space Launch System compare with some of history's greatest launchers?



SPACE SHUTTLE
Years of service: **1981-2011**
Payload to low-Earth orbit (tons): **27.5**
Cargo: **Satellites, probes and astronauts**
Destinations: **International Space Station, Hubble Space Telescope**

ARIANE 5 ES
Years of service: **2008-present**
Payload to low-Earth orbit (tons): **21**
Cargo: **Rosetta, Automated Transfer Vehicle**
Destinations: **Geostationary transfer orbit, long term orbit**

ATLAS V 551
Years of service: **2006-present**
Payload to low-Earth orbit (tons): **18.8**
Cargo: **Juno, New Horizons**
Destinations: **Low-Earth orbit, geostationary transfer orbit**

DELTA IV HEAVY
Years of service: **2004-present**
Payload to low-Earth orbit (tons): **28.8**
Cargo: **Orion Multi-Purpose Crew Vehicle, Orion satellites**
Destinations: **Low-Earth orbit, geosynchronous transfer orbit**

FALCON 9 V1.1
Years of service: **2015-present**
Payload to low-Earth orbit (tons): **13.2**
Cargo: **Communications satellites**
Destinations: **Low-Earth orbit**

VEGA
Years of service: **2012-present**
Payload to low-Earth orbit (tons): **1.5**
Cargo: **Smaller satellites**
Destinations: **Low-Earth orbit, Sun-synchronous orbit, polar orbit**

SPACE LAUNCH SYSTEM (SLS) BLOCK 2
Years of service: **From 2018**
Payload to low-Earth orbit (tons): **130**
Cargo: **Four astronauts**
Destinations: **Beyond low-Earth orbit, asteroids, Mars**

SATURN V
Years of service: **1967-1973**
Payload to low-Earth orbit (tons): **140**
Cargo: **The Apollo missions to the Moon, Skylab space station**
Destinations: **Beyond low-Earth orbit**

Why is the Solar System flat?

How a matter-filled cloud turned into a flat, planetary system

To find out why our Solar System is flat, we must first uncover its origins. Our Solar System formed from a huge, nebulous cloud of gas and dust, roughly 4.6 billion years ago. This shapeless, spinning cloud contained all of the matter that makes up the Sun, planets and other objects in the Solar System.

Although it seems unlikely that something measuring light years across would ever become flat, there is a reason for this bizarre phenomenon. When particles in a cloud are randomly crashing into each other their individual paths are impossible to predict, yet when all the particles are considered collectively, they have a total angular momentum (a net amount of rotation). Therefore, the cloud as a whole spins about its centre of mass in one direction.

As the particles collided they shot off randomly, but the up and down collisions worked to cancel each other out. Although they lost energy individually, the energy was not lost from the overall system. This is due to a rule known as the conservation of angular momentum – the total amount of spinning in any isolated system, such as the Solar System, will always remain constant. This allowed the cloud to flatten over time, losing its height and becoming the roughly two-dimensional disc we see today.

It's not just our Solar System that's flat – the Milky Way, Saturn's rings, exoplanet systems and other galaxies also lie on a single plane

Cannibal galaxies

Inside the galaxy-eat-galaxy world of the cosmic food chain

While small galaxies create new stars from gas and dust, their more massive counterparts grow by gobbling up what's around them. The very strong gravitational forces they exert pull on smaller galaxies that can be millions of light years away, sending the two racing towards each other until they merge in a spectacular galactic feast. This can currently be seen happening between the distant Antennae galaxies, which began colliding a few hundred million years ago.

However, this galactic cannibalism has also been observed much closer to home. A stream of debris, known as the Sagittarius Stream and extending out from our very own Milky Way, is believed to contain the leftovers of its last meal. The stream contains stars that are still travelling in the direction from which they came, creating a trail of breadcrumbs leading to their original source, the nearby Sagittarius dwarf galaxy.

Eventually, it will be the Milky Way's turn to be on the menu, as it is expected to collide with the much larger Andromeda galaxy in about 4 billion years. When this happens, computer simulations have revealed that there is a one in ten chance that our Solar System will be evicted from this new galaxy, making the night sky appear far darker. However, it's more likely that we will end up closer to the core of 'Milkomeda', filling our night sky with even more stars.

Massive galaxies fatten themselves up by feasting on smaller, nearby galaxies

THREE MORE SCARY SPACE OBJECTS

Stellar vampires

Many of the stars in our galaxy share their space with another star, forming a binary system. The one with the lower mass can suck away the other's hydrogen, using the gas to fuel itself. This increases its mass until it strips its neighbour's stellar envelope completely.

Franken nebula

It may look like Frankenstein's menacing monster, but this is actually the open star cluster NGC 2467, located 20,000 light years away in the Puppis constellation. It contains hundreds of hot, massive stars belching out radiation to sculpt the clouds of the nebula into an eerie, colourful shape.

Little Ghost nebula

When a star the size of our Sun ran out of hydrogen and switched to using helium, its temperature soared. Eventually it expanded and became a red giant, which expelled its outer layers into space, creating a nebula. After about 10,000 years, the stellar remnant in the centre of the Little Ghost nebula will begin to cool off, forming a white dwarf star.

The Terracotta Army

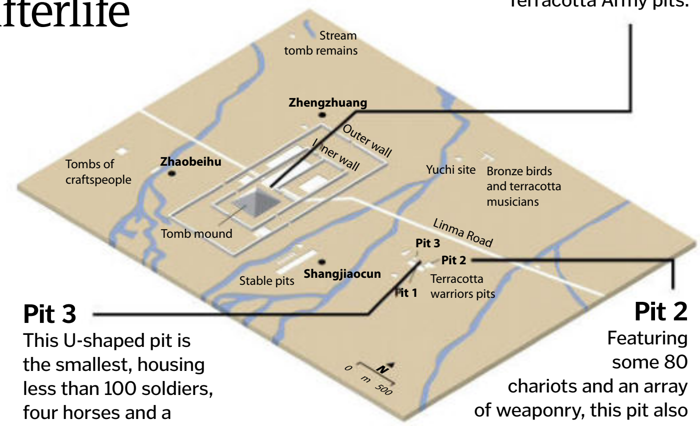
Learn about China's ancient warriors for the afterlife

The eighth wonder of the Ancient world was discovered by accident. In 1974 in Xi'an, China, a group of farmers were digging when they uncovered a pit containing thousands of life-size warriors. The Terracotta Armyis part of an enormous mausoleum, built to accompany the First Emperor into the afterlife.

Over 2,000 years ago, Emperor Qin (pronounced Chin) Shi Huang, had united the seven warring states into the single nation of China, which gets its name from his kingdom. The resulting peace meant there was no use for his vast army, so he set them to work building his elaborate tomb.

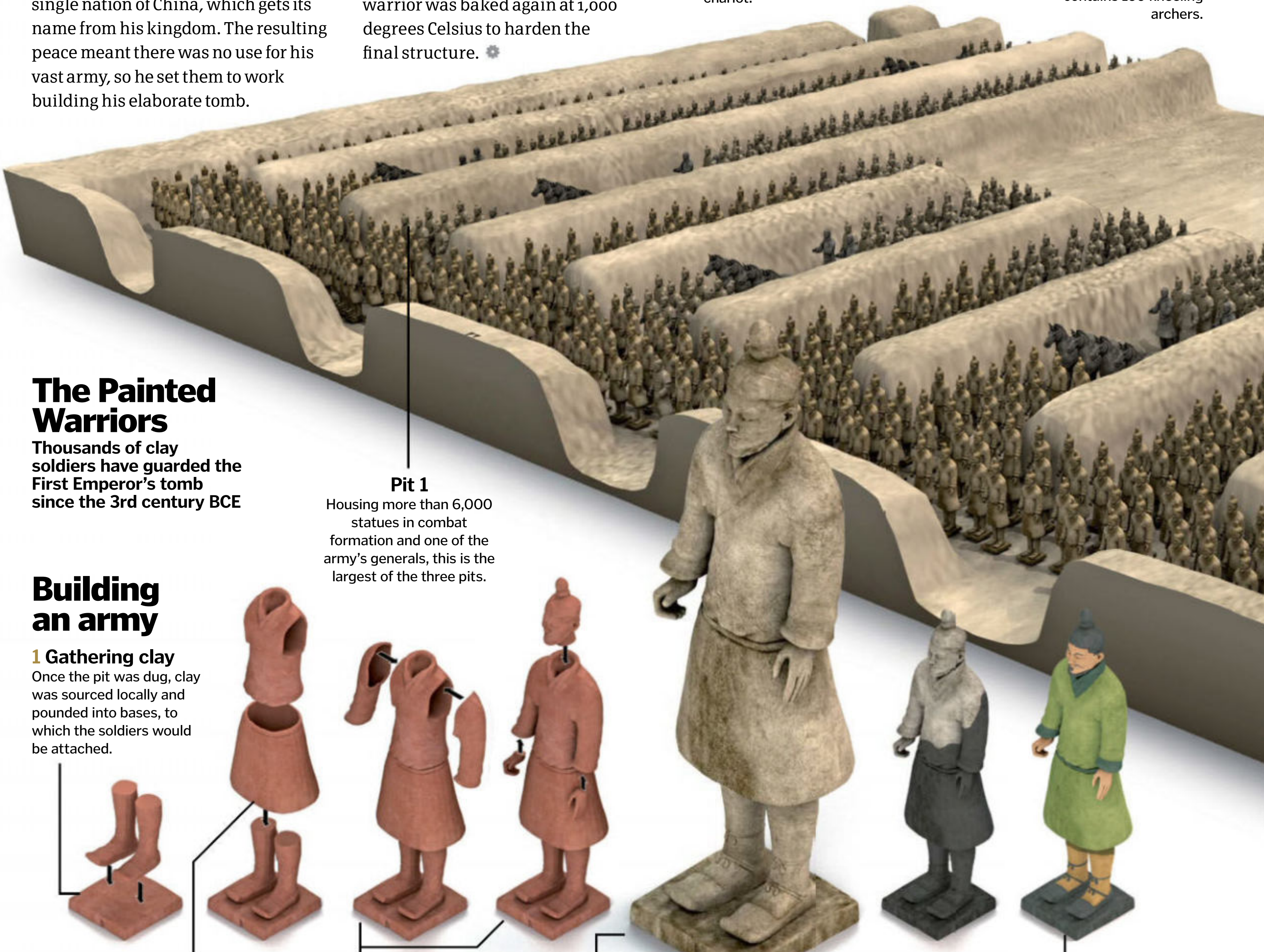
Much like the whole of Chinese society at the time, the Emperor was obsessed with life after death. He believed that the next world mirrored this one, so commissioned an army of life-size clay warriors to help maintain his rule. The pits were excavated and clay bases were made for each figure. All the body parts was made separately and baked in a kiln before being joined in an early example of assembly-line construction. Once complete, each warrior was baked again at 1,000 degrees Celsius to harden the final structure.

The mausoleum
The First Emperor's tomb lies beneath a huge earth mound, about 1.5 kilometres from the Terracotta Army pits.



Pit 3
This U-shaped pit is the smallest, housing less than 100 soldiers, four horses and a chariot.

Pit 2
Featuring some 80 chariots and an array of weaponry, this pit also contains 160 kneeling archers.



The Painted Warriors

Thousands of clay soldiers have guarded the First Emperor's tomb since the 3rd century BCE

Pit 1
Housing more than 6,000 statues in combat formation and one of the army's generals, this is the largest of the three pits.

Building an army

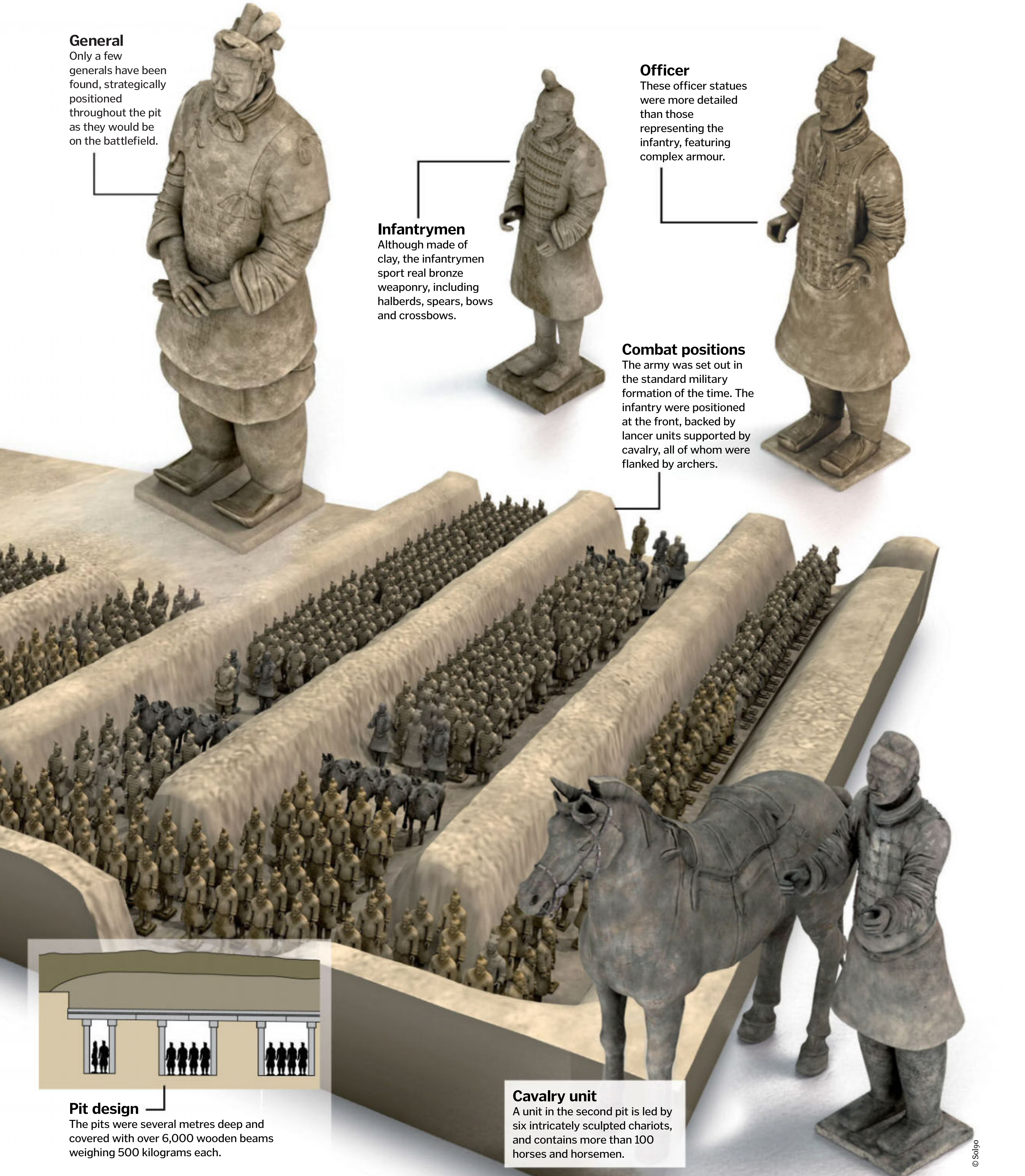
1 Gathering clay
Once the pit was dug, clay was sourced locally and pounded into bases, to which the soldiers would be attached.

2 Making the parts
Each soldier's arms, torso, legs, hands and head were made using a variety of moulds.

3 Assembly and sculpture
Sections were baked and combined to form the clay soldier. Individual facial features were then added.

4 Firing the clay
After assembly, the soldier was baked again to harden the clay.

5 Painting
The finished soldiers were painted with bright colours, as they were expensive to make and thus symbols of luxury.



General
Only a few generals have been found, strategically positioned throughout the pit as they would be on the battlefield.

Infantrymen
Although made of clay, the infantrymen sport real bronze weaponry, including halberds, spears, bows and crossbows.

Officer
These officer statues were more detailed than those representing the infantry, featuring complex armour.

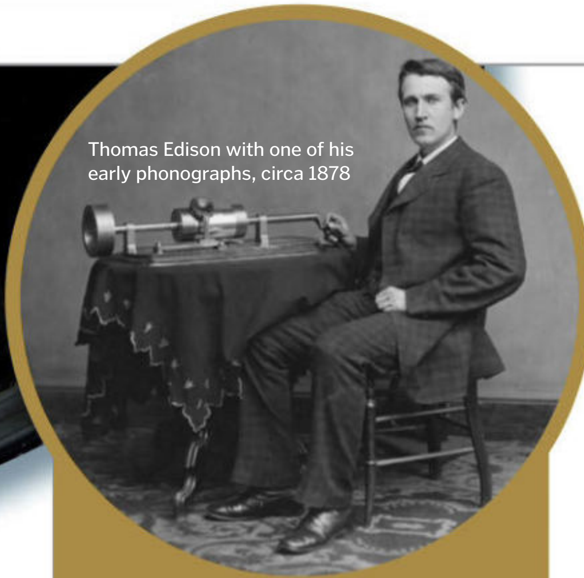
Combat positions
The army was set out in the standard military formation of the time. The infantry were positioned at the front, backed by lancer units supported by cavalry, all of whom were flanked by archers.

Pit design
The pits were several metres deep and covered with over 6,000 wooden beams weighing 500 kilograms each.

Cavalry unit
A unit in the second pit is led by six intricately sculpted chariots, and contains more than 100 horses and horsemen.

How vinyl records were made

Take a spin around this retro method of mass-producing music



Thomas Edison with one of his early phonographs, circa 1878

As the vinyl disc spins on the record player, a needle – or stylus – moves along the grooves on its surface. It vibrates as it traces over the thousands of tiny bumps and the music plays. The tech seems simple compared to an iPod or a wireless speaker, yet the process to make one of these vinyl records is quite intricate.

Once engineers had perfected the recording in the studio, they would create a master disc. This was made of aluminium and coated with a black lacquer. A machine equipped with an electronic cutting stylus, or needle, would etch the grooves into the lacquer, its path directed by electrical signals from the audio. The finished record was coated with a layer of metal, such as silver or nickel, and this so-called master would form the mould for all the records that would be produced. Liquid nickel was poured into the cast to create a 'stamping record' – a negative version of the record with ridges instead of grooves – and this was connected to a hydraulic press and used to directly print into the vinyl. The stamping record would be lowered onto the vinyl (which was softened by heating with steam) to squeeze it into its final shape and imprint the audio. The disc was then removed, hardened in a water bath, and cut to size using a sharp blade.

Before the records could be sold, a handful were inspected for sound quality. Flawed copies were melted and pressed again.

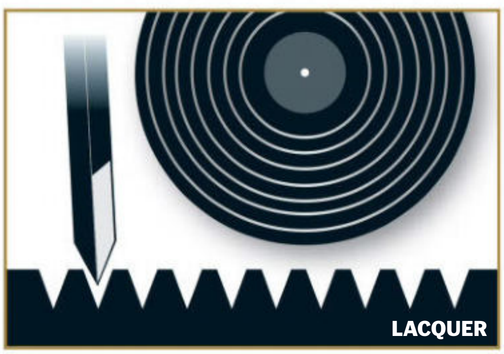
Thomas Edison's phonograph

The inventor of the electric light bulb and the motion picture camera was also the grandfather of modern record players. In 1877 Thomas Edison and his assistants were working on a way to record telegraph messages using paper strips wrapped around rollers. He attached a needle to the diaphragm in a telephone mouthpiece, which vibrated with sound energy when someone spoke, creating squiggles on the paper. Once the sound was recorded in this way, it could be replayed by rotating the cylinder in the opposite direction, which dragged a second needle backwards through the indentations the first had made. Edison and his team produced a working prototype, recording their own rendition of *Mary Had A Little Lamb.*

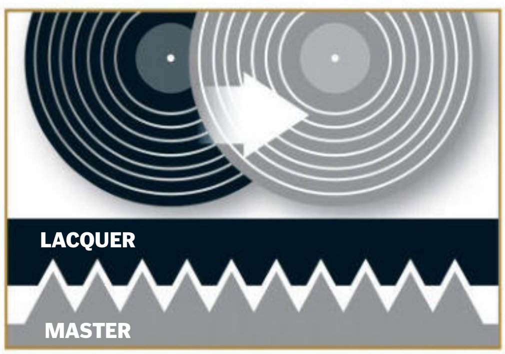
Within six months, Edison had replaced the paper strips with tinfoil to improve the sound quality, and the first phonograph was born. Edison's work paved the way for other inventors to refine and improve the recording process, which eventually led to the record player and vinyl records.

Making a hit record

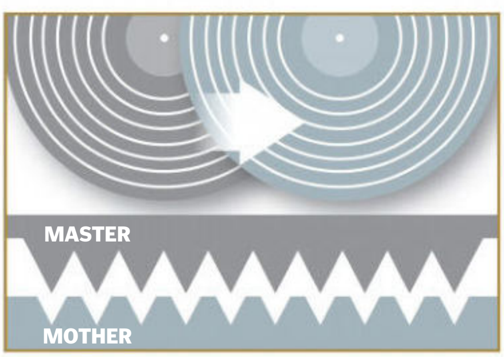
From the studio to your turntable



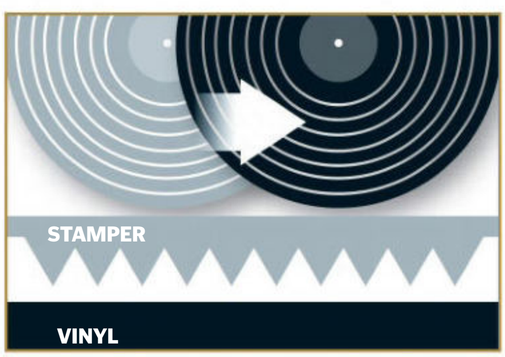
1 Cutting the lacquer
Tiny grooves were etched into the lacquered discs by a record-cutting machine's needle. This was guided by the audio of the specific song.



2 Producing the master disc
The lacquer was not tough enough for the production process, so was coated with silver or nickel. It was then peeled off and discarded, leaving the metal master.



3 Creating the 'mother'
The master was re-cut once more to make a mother record. This was then replated to create the 'stamper', which could then be used to mass produce the record.



4 Stamping the vinyl
A fresh piece of vinyl was sandwiched between the stamper and a hydraulic press. Steam was used to soften the vinyl, enabling the stamper to imprint it with grooves.

5 Quality control
Before the finished vinyl could be sent to shops, a few were played to check that they were working correctly and that there were no imperfections.

Beer through the ages

The history of the world's most widely consumed alcoholic tipple

1988
PLASTIC WIDGETS
Invented originally for Guinness, plastic widgets are nitrogen-filled spheres. Now common in many lightly carbonated beers, they help release some of the dissolved carbon dioxide bubbles when pouring, creating a frothy 'head'.

1933
BEER CAN
The Gottfried Krueger Brewing Company was the first to produce beer cans, initially creating 2,000 which were given to its customers to trial. The original aluminium design weighed roughly seven times the average beer can today.

1858
FERMENTATION
The French chemist Louis Pasteur demonstrated that yeast was responsible for fermenting sugar into alcohol. He also showed that bacterial life could spoil beer, and invented a method called pasteurisation that killed microbes with heat.

Circa 1500
GROWING POPULARITY
During the Middle Ages, beer became hugely popular, particularly in Europe. In 1516 Germany introduced the first purity law, stating that beer may only be brewed from water, hops and barley.

Circa 800
HOPS
The first written evidence of hops being used as a beer ingredient is from a French monastery. By the 13th century they were used as a preservative, replacing traditional mixes of herbs and spices, and imparting a bitter, tangy flavour.

Circa 9000-7000 BCE
BARLEY
Although beer's true origins are unknown, many believe it was invented by accident during the Neolithic era. Wild yeast may have settled on barley that had germinated, starting the fermentation process and creating alcohol.

A BLUFFER'S GUIDE TO THE BERLIN WALL

Five fast facts about the defining symbol of the Cold War

1 It fell by mistake
On 9 November 1989, East German politician Günter Schabowski prematurely announced that the Wall's travel restrictions would be lifted immediately. The original plan was for East Germans to apply for a visa to gain access to the West, but once a mob of angry protestors gathered, the gates were opened that very same day.

2 The Wall contained many layers
East and West Berlin were actually separated by two concrete walls, with tall wire fences either side. Between the towering concrete structures was the 'death strip', a gap up to 150 metres wide filled with watchtowers and trip-wire that could trigger automatic guns, all to deter people from crossing.

3 It separated three 'zones' from the Soviet sector
After World War II, Germany was divided into four sections – three of these were controlled by Western countries (Britain, the US and France) while the Soviet Union ruled over the fourth. The Berlin Wall split the three Western sectors from the Soviet-governed fourth, preventing East Germans from crossing into the western part of the capital.

4 5,000 people tried to escape before it fell
Many East Berliners were desperate to escape to the more lucrative West, and would often stow away in cars or dig underground tunnels to try and reach the other side. Some border guards were also keen to flee – among the very first successful escapees was an East German guard, two days after the Wall's gates were sealed.

5 JFK was relieved when the Wall was built
Before the Wall was erected, there was talk of Soviet forces blockading West Berlin if Western forces did not leave. When the Soviet Union announced the construction of the Wall, President John F Kennedy is said to have confided: "It's not a very nice solution, but a wall is a hell of a lot better than a war."

Mexican bandits

Meet the outlaws who fought in the Mexican Revolution

In 1910, the Mexican people had endured 34 years under President Porfirio Díaz. Since coming into power in a coup in 1876, the long-serving dictator had controlled elections and placed any land and power firmly in the hands of the elite. The lower classes had had enough.

When pro-democracy advocate Francisco Madero dared to challenge Díaz for power in 1910, the president had him jailed. However, Madero escaped from prison and, since he had already gained much support from the poor, called for his followers to revolt against the government. Armies of revolutionaries began to spring up across the country.

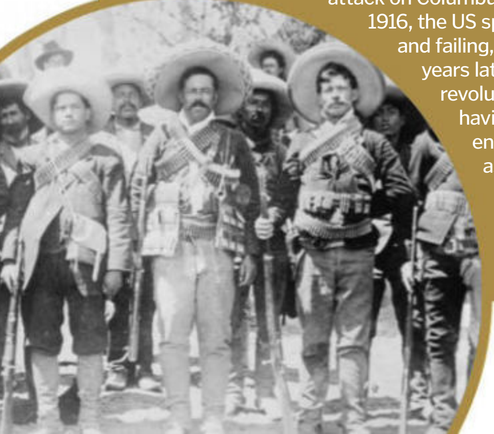
These gangs of bandits and outlaws were often depicted as Mexican Robin Hoods, using all the firepower they could get their hands on to steal from the rich and give to the poor. They managed to successfully oust Díaz in May 1911 by attacking the city of Ciudad Juárez, but this didn't put a stop the political unrest.

Madero's slow pace of reform caused the revolutionaries to turn against him, and Victoriano Huerta soon overthrew him. Huerta turned out to be even worse than Díaz, causing gangs of bandits to join forces in an attempt to topple him. However, the groups soon began to turn on each other and even against the US, resulting in many bloody conflicts and cavalry charges. Several leaders later, the revolution came to a close in 1920, but the legend of the Mexican bandits lives on to this day.

Pancho Villa: thief or folk hero?

With a bandolier slung over each shoulder, Francisco 'Pancho' Villa was one of the most famous bandits of the Mexican Revolution. His life of crime began at the age of 16, when to protect his sister, he killed the abusive owner of the estate where he worked. He spent the next few years running from the law, and became the leader of a bandit gang that committed crimes against the wealthy.

When the revolution began in 1910, Moderno put Villa in charge of the revolutionary forces and he became a folk hero. He began to rob the rich on a larger scale, running unpopular landlords out of the country and distributing their property amongst the poor. After leading an infamous attack on Columbus, New Mexico in 1916, the US spent a year trying, and failing, to capture him. Four years later he retired from revolutionary life, but having made so many enemies, he was assassinated in 1923.



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Pancho Villa (centre) dressed for battle with his revolutionaries

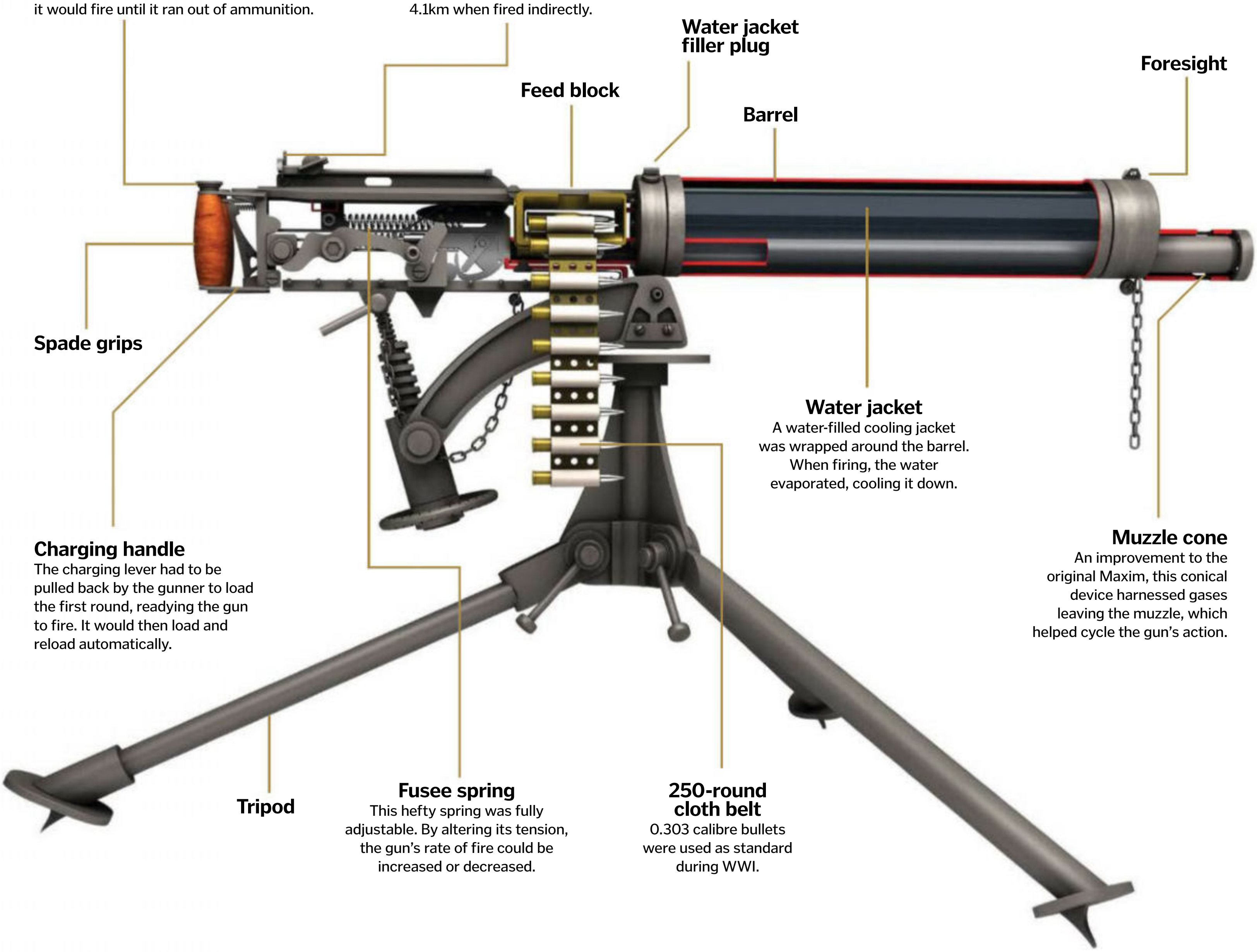
Ready for battle

The essential kit for Mexican revolutionaries

"These gangs of bandits and outlaws were seen as Mexican Robin Hoods"

Ready, aim, fire!

Clever engineering prevented malfunction in the heat of battle



WWI's Vickers-Maxim gun

Stare down the barrel of this deadly British weapon

The Vickers-Maxim machine gun obliterated battlefields, rattling off over 450 rounds a minute. It entered service in time to see action during World War I and served the British Army for more than 50 years.

The key to the design was that it used the power of the cartridge explosion to reload and re-cock the gun after each shot. This became known as a recoil system, as the forward force of the bullet produced an opposing force – the recoil. The force generated pushed the bolt and barrel backwards, while they were locked together. A small metal catch then unlocked the two parts as they moved backwards, before the spring pushed the barrel forward again. The backward motion also ejected the used shell, and a new cartridge was automatically loaded into place from the ammunition belt. If the trigger was still depressed, the whole cycle started again and another shot would fire almost immediately.

Although the Vickers was rather heavy and required a team of six to operate, it was extremely reliable. During a British attack in 1916, it's estimated that ten Vickers fired more than one million rounds in just 12 hours.


Men from 5th (Scots) Parachute Battalion, 2nd Parachute Brigade, fire a Vickers machine gun from a rooftop in Athens in 1944

BRAIN DUMP

Because enquiring minds need to know...

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MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Ella Carter

Fascinated by the underwater realm, Ella studied marine biology and oceanography at university before embarking upon a career in publishing. She adores the natural world and loves researching and writing about the wonders within.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

ISS astronauts and the objects around them are in a constant state of free-fall

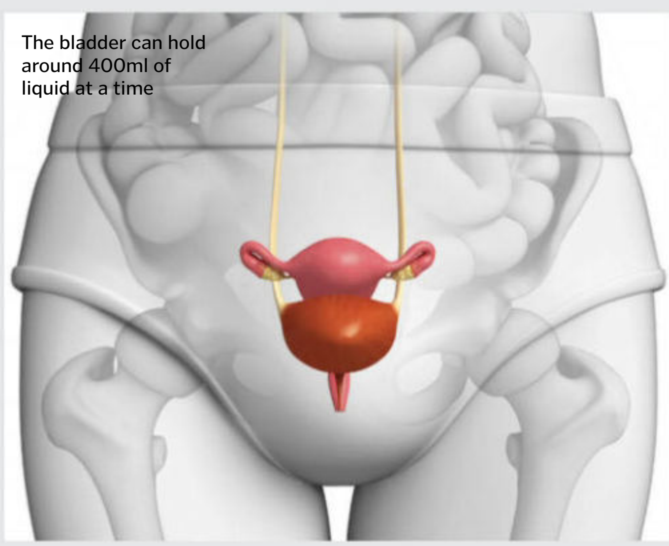
Why are astronauts weightless inside the ISS?

Dean Wainwright

■ ISS astronauts are not truly weightless as they are still affected by the Earth's gravitational pull, but the lack of other forces pushing on them leads to the perceived sensation of weightlessness.

Down here on planet Earth we experience gravity on a daily basis, as well as opposing contact forces. These forces are exerted through the ground we stand on, and give us a sense of our own weight.

The ISS is in orbit around the Earth, meaning that it is actually constantly 'falling' towards the Earth. It is in this state of perpetual free-fall that astronauts don't experience any contact forces, and therefore they end up feeling weightless. **AC**



The bladder can hold around 400ml of liquid at a time

How long can a human go without peeing?

Charlie Sims

■ Our kidneys are constantly filtering blood to remove waste from our bodies, so urine production never stops. With a normal daily intake of around 2,000 millilitres of water, we can expect to produce between 800 and 2,000 millilitres of urine – that's enough to fill the bladder up to five times over. However, if we drink less, the rate of production slows. The kidneys still produce a little bit of urine even when we aren't drinking, but it is much more concentrated, helping to remove waste products without wasting water. Output can drop as low as 400 millilitres per day before doctors start to worry – enough to fill the bladder just once. **LM**

Next time there's a spill, reach for the sodium carbonate

How can baking soda get rid of stains?

Tomas Hayward

Instead of baking soda, which is sodium bicarbonate, the best thing to use is sodium carbonate – an old-school household cleaner sometimes called soda crystals or washing soda. Both substances work because they're alkaline, and the red wine is acidic. Red wine can stain because of natural dye pigments found in grape skins, called anthocyanins. These pigments change colour with pH, and so when a strong alkali solution is applied to the stain, the colour of the anthocyanins can sometimes be lightened. It's worth bearing in mind, though, that this method isn't foolproof – every stain is different and so results can vary greatly. **EC**

How do smartphones keep you awake?

Suzie Nettleford

A smartphone by your bed will subject you to a barrage of pings from Facebook posts, texts and emails. But even if you're just browsing the web or reading a book on your phone, with the volume down, your mobile is interfering with your sleep. That's because LCD screens give out a lot of light at the blue end of the spectrum.

Blue light suppresses the production of melatonin, a hormone that makes us feel sleepy. We evolved our sleep cycle millions of years ago when the only source of blue light was the Sun, and our melatonin system takes advantage of this to make us awake during the day and sleepy at night. Phone, tablet and laptop screens disrupt this system. **LV**

The blue light on phones can disrupt your sleep

The greater horseshoe bat hibernates in a cave

How do bats sleep upside down without falling?

Hattie Mallaby

Bats' legs are rotated 180 degrees so their knees appear backwards to us, and special tendons in their toes stay flexed so that they don't have to use up any energy to hang on – they only need to let go to fly. In fact, those tendons are so strong that bats continue to hang after they die. As bats are generally very small, hanging upside down doesn't affect their blood flow the way it does ours. They don't get dizzy, and their ability to hang upside down means that bats can roost in places no other animal can. **SF**

Why do dogs smell each other's bottoms?

Florence Tate

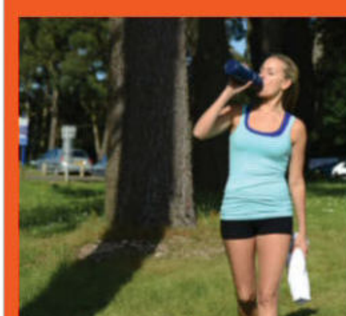
Dogs have an incredibly keen sense of smell – up to 100,000 times more sensitive than our human noses. When dogs meet each other, they can gain a whole lot of information about their new companion just from sniffing them, and the best place to sniff is the rear end. Next to the dog's anus are anal glands – small sacs secreting substances that allow dogs to communicate chemically with one another. These secretions are used to mark territory and contain specific chemicals depending on the dog's diet, gender and even emotional state. Dogs have a special organ in their nose, called the Jacobson's organ, which allows them to process and interpret these chemical signatures. That's why they're able to glean all that info without being overpowered by the smell of poop. **EC**

Dogs get all the details they need about their new friends from a quick sniff

FASCINATING FACTS

How much water can kill you?

Drinking just six litres of water in a short time has been known to cause water intoxication. This is a potentially lethal condition where excess water in the bloodstream starts to upset the body's natural electrolyte balance. **AC**



Water intoxication is very rare but can be deadly

Sat navs use GPS coordinates to plot your route

How do sat navs know which way you are facing?

Hadley Mills

Sat navs have an electronic compass built into their circuit boards. This uses a thin strip of nickel-iron alloy, called permalloy, which changes its electrical resistance according to the magnetic field. By arranging three strips at right angles to each other and comparing their resistance, you can work out which way is magnetic north. That gives a stationary compass bearing. They can also plot your course from GPS coordinates to find your direction, giving more accurate results. This is called a differential compass bearing. **LV**

Deep-sea fish have very slow metabolisms, as energy is precious in the depths

How do fish survive the pressure underwater?

Robyn O'Neill

Pressure underwater increases by one atmosphere every ten metres, so at the bottom of the abyssal plain 6,000 metres down, the pressure is a weighty 600 atmospheres, equivalent to balancing a jumbo jet on your big toenail! Fish that live this deep down in the ocean survive the extreme conditions by maintaining the same pressure inside their bodies as outside. Their cell membranes are made of a 'squishier', less rigid substance, their muscles are flabby and watery and their bones are weak, unlike us humans who cannot adapt the same way. This all helps to ensure that the pressure effects on the fish's tissues are consistent with the surrounding water. **EC**

FASCINATING FACTS

When did the prehistoric era end?

One definition of 'prehistory' is the time before life appeared on Earth. Fossils containing tiny organisms called stromatolites have been dated to 2.7 to 3.5 billion years ago. By contrast, the first human-like beings only appeared about 6 to 8 million years ago. **SF**

Stromalites are layered structures containing microorganisms, the fossils of which may be 3.5 billion years old

Where does the saying 'not my cup of tea' come from?

Brits love tea, and referring to something pleasing as 'my cup of tea' began in the 1930s. The phrase adopted a negative connotation, meaning 'not something I enjoy' during WWII. **EC**

Is a cup of tea not your cup of tea?

Why is Siri female?

The default voice for Siri is only female in the US and Australia; in the UK it is male. Apple has never explained why this is, but you can change it under Settings>General>Siri>Siri Voice. **LV**

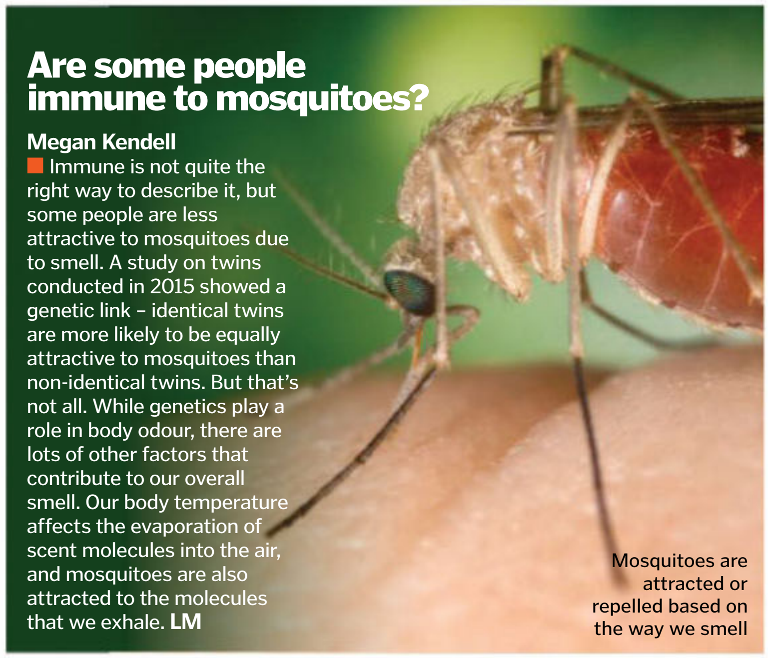
Why the standard gender for Siri is different by country is a mystery

It takes temperatures well below 0°C to freeze salt water

How does salt melt ice?

Samantha Pusey

Salt lowers water's freezing point, accelerating the melting process. Melting ice involves breaking bonds between the water molecules, so it requires a large amount of heat energy. Ice actually gets cooler as it melts. On the surface of an ice cube, water is continually melting and refreezing. Adding salt makes it harder for the water molecules to form the bonds needed to make ice, allowing the melting process to dominate. This trick won't work in very cold temperatures – if it is too cold for the ice to begin to melt, the salt will simply sit on top. **AC**



Are some people immune to mosquitoes?

Megan Kendell

Immune is not quite the right way to describe it, but some people are less attractive to mosquitoes due to smell. A study on twins conducted in 2015 showed a genetic link – identical twins are more likely to be equally attractive to mosquitoes than non-identical twins. But that's not all. While genetics play a role in body odour, there are lots of other factors that contribute to our overall smell. Our body temperature affects the evaporation of scent molecules into the air, and mosquitoes are also attracted to the molecules that we exhale. **LM**

Mosquitoes are attracted or repelled based on the way we smell

Why can some people eat hotter food than others?

Polly Lavelle

Tolerance for spicy food is partially inherited, but repeated exposure can also desensitise pain receptors. The sensation of eating spicy food is produced by the trigeminal system, which along with our sense of taste and olfactory system, allows us to perceive flavours. The capsaicin in spicy foods activates pain and heat receptors. Those who eat spicy food have less sensitive pain receptors. Eating spicy food regularly at a young age kills off nerve endings, increasing people's capacity to eat curries and chillies. **AC**

Pain or pleasure? Not everyone enjoys eating spicy food

Small boxes make cats feel safe

Why do cats love cardboard boxes?

Georgina O'Connor

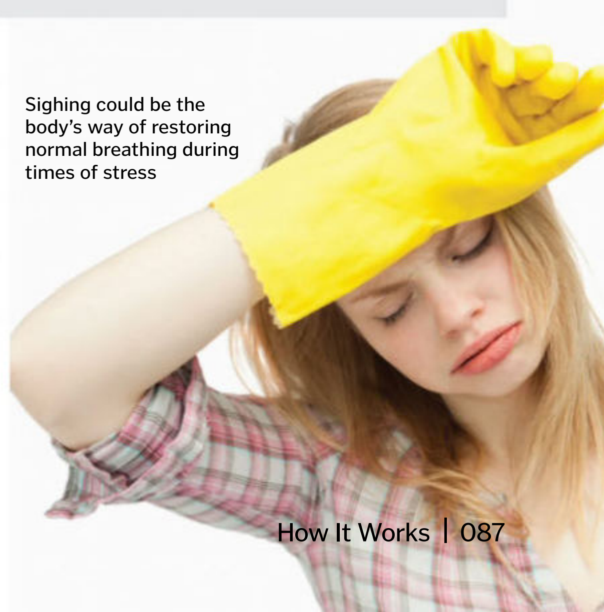
For cats, boxes are the perfect hangout and napping spot. If they're stressed, their natural response is to hide, so a box is a great shelter. Cats prefer warm, ambient temperatures (around 25 to 35 degrees Celsius) and cardboard is a good insulator. They often squeeze into small boxes because they can curl up into a tight ball and maintain their body temperature. **SF**

Why do we sigh?

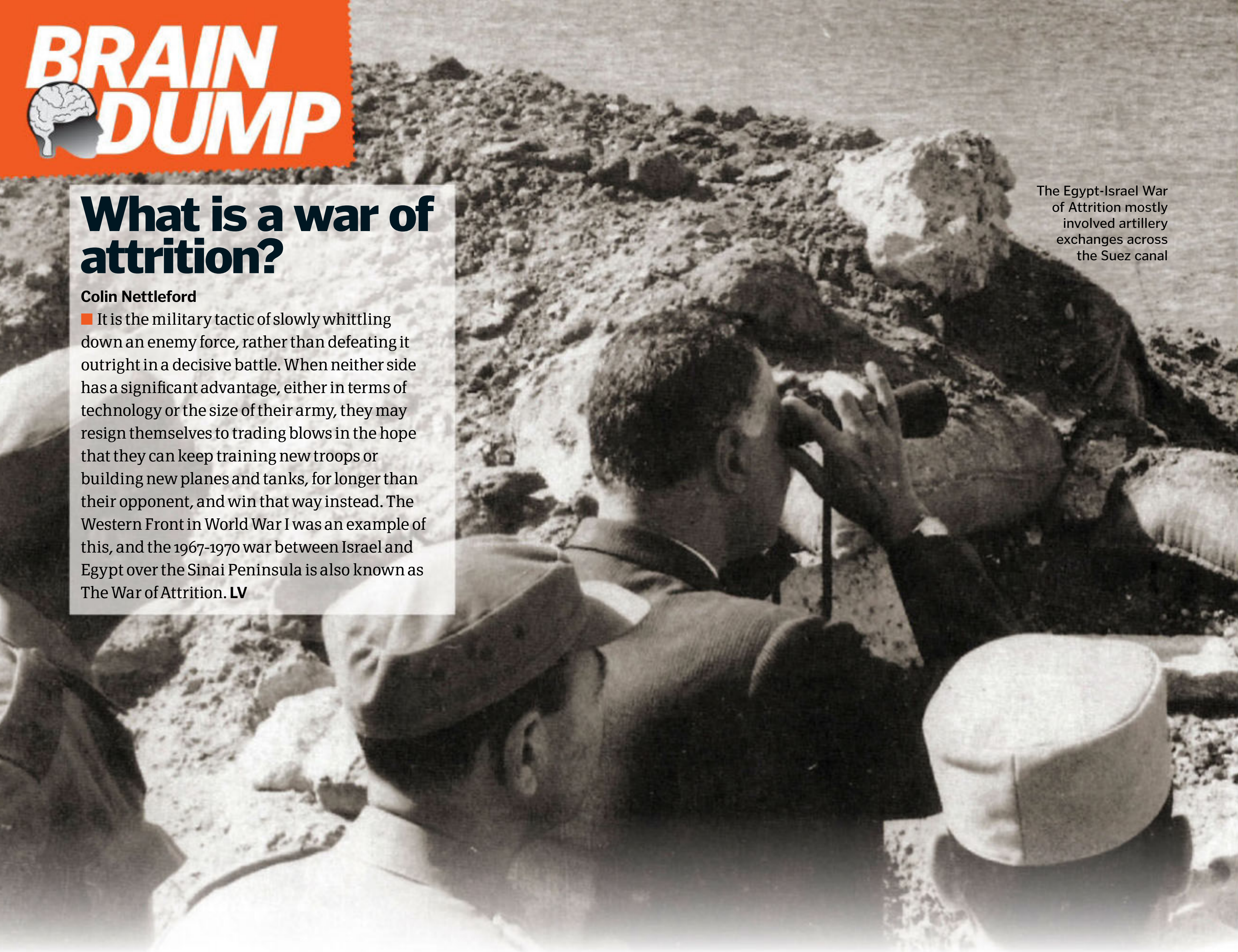
Nicole Murdoch

This question was tackled by psychologists in Norway, originally just to demonstrate to their students that some fields haven't been very well studied yet. The researchers performed a series of experiments, including giving the students challenging puzzles to complete, and watched out for sighing. They concluded that people sigh as the result of frustration, but that to onlookers it can appear as though they are sad or disappointed. They were also given a questionnaire to determine what emotions they related to sighing, with options such as active versus passive feelings and intense emotions versus subdued ones.

The physiological reason for the sigh has since been investigated by a team of scientists in Belgium, who showed that it could be a way for the body to return to normal breathing patterns after stress. **LM**



Sighing could be the body's way of restoring normal breathing during times of stress



The Egypt-Israel War of Attrition mostly involved artillery exchanges across the Suez canal

What is a war of attrition?

Colin Nettleford

It is the military tactic of slowly whittling down an enemy force, rather than defeating it outright in a decisive battle. When neither side has a significant advantage, either in terms of technology or the size of their army, they may resign themselves to trading blows in the hope that they can keep training new troops or building new planes and tanks, for longer than their opponent, and win that way instead. The Western Front in World War I was an example of this, and the 1967-1970 war between Israel and Egypt over the Sinai Peninsula is also known as The War of Attrition. **LV**

FASCINATING FACTS

What was the first anaesthetic?

The first anaesthetic used to knock a patient out during surgery was ether. Doctors had considered using nitrous oxide (laughing gas) before, but it didn't keep people asleep for long enough – a scary thought! **LM**

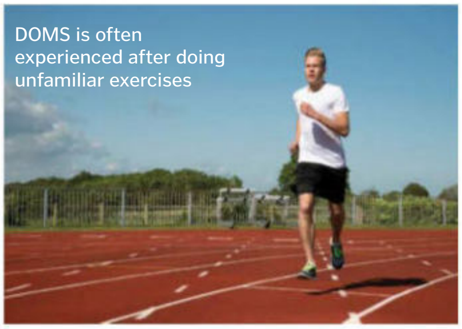
Lots of anaesthetics have been tried over the years, including chloroform

How did the Romans pronounce their numerals?

Julian Wirral

Latin uses words for numbers that closely resemble other European languages and have nothing to do with the Roman numerals used when writing. The numbers one to ten in Latin are: unus, duo, tres, quattuor, quinque, sex, septem, octo, novem and decem. The number 38 is XXXVIII in Roman numerals but triginta octo in Latin. The exact pronunciation varied through history and across different dialects, but the v in novem was actually pronounced as a w and decem was pronounced 'dekem'. September, October, November and December were all named because they were originally the seventh, eighth, ninth and tenth months in the Ancient Roman calendar. **LV**

Roman numerals were often used inconsistently, such as IIII instead of IV for 4



DOMS is often experienced after doing unfamiliar exercises

Why do your muscles feel stiff after exercising?

Mariana Ferdenzi

The stiffness and tenderness that follows intense exercise is known as delayed onset muscle soreness (DOMS). As the name might suggest, it does not happen as soon as the exercise is over, and instead often appears the morning after.

DOMS is not caused by lactic acid, which is rapidly cleared from overworked muscles as soon as blood flow and oxygen return to normal. It is actually caused by microscopic damage to the structure of the muscle itself. Fluid leaks into the muscles as the body tries to repair the damage, causing them to swell slightly, and making them feel stiff and sore. **LM**

By observing how dark matter distorts light (shown in blue), its presence can be inferred

What is the difference between dark matter and dark energy?

Jack Buchanan

Very little is known about dark energy, other than it is a force causing our universe to expand. Dark matter makes up roughly 27 per cent of our universe, with dark energy contributing 68 per cent. Dark matter cannot be observed directly, but astronomers infer its existence from the gravity it exerts on surrounding objects – this gravitational pull holds our universe together.

Like visible matter, scientists believe dark matter is made up of particles, although these particles are different to the ones we are familiar with. Dark energy was first discovered in the Nineties, when scientists first realised that the universe's expansion was accelerating rather than slowing down.

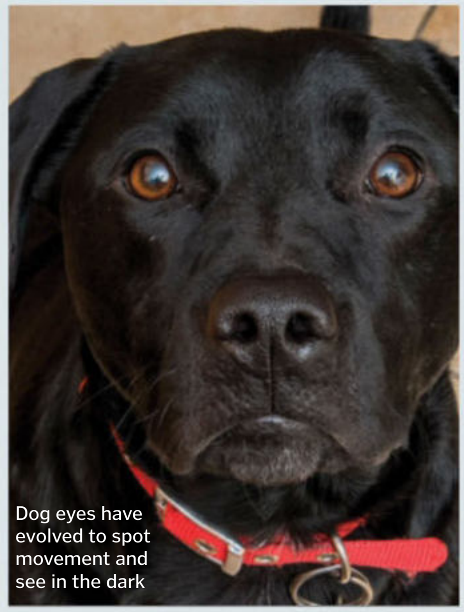
We still don't understand the mechanism by which dark energy drives this expansion. **AC**

The emulsifiers in processed cheese help it to melt without the fat separating

What is processed cheese made of?

Bex Turan

Processed cheese ingredients vary depending on its form – whether it's a slice, a spread or a sauce. In general, processed cheeses contain some percentage of one or more types of solid or powdered cheeses, but they may also contain several other ingredients, including cream, whey, water, emulsifiers, saturated vegetable oils, salt, sugar, spices and food colourings. Different countries have different rules about naming conventions but if it's called something like processed cheese, processed cheese food, or processed cheese spread, you can usually be sure that it only contains a proportion of actual cheese. **SF**



Dog eyes have evolved to spot movement and see in the dark

Why are dogs' irises so big?

Lina Notton

Dogs have large irises compared to humans because their eyes have evolved to quickly spot movement and to see well at night; before they were domesticated, dogs tended to be most active at dawn and dusk. On the other hand, unlike humans, they don't have very good depth perception, colour perception, or the ability to see details. Dogs' retinas contain rod and cone cells just like humans', but they have only two types of cones as opposed to our three. This means they probably don't see red or green and mostly see things on a yellow, blue and grey scale. Dogs also have a higher ratio of rods to cones, which in turn helps them to see well in low light. **SF**

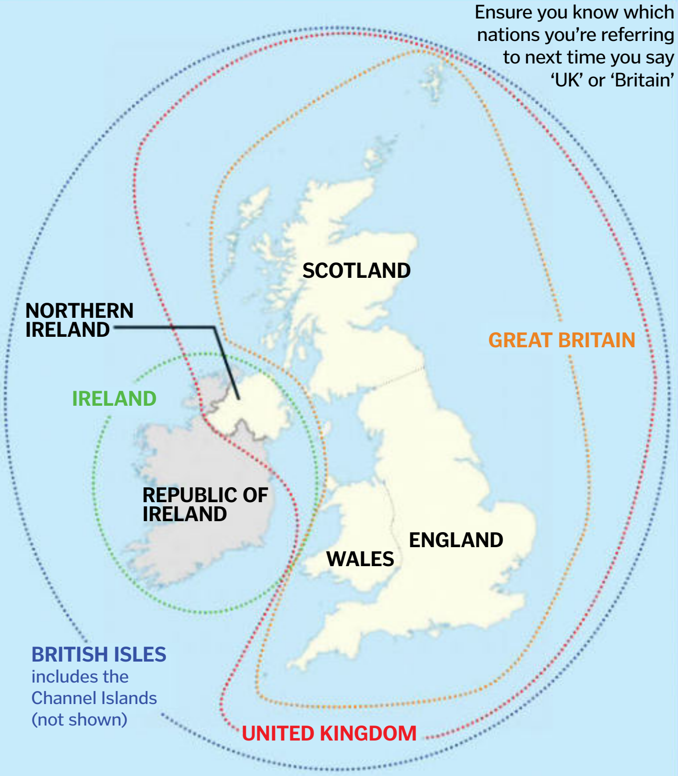
What's the difference between the UK and Great Britain?

Maxine Santry

The full name for the abbreviation 'UK' is 'The United Kingdom of Great Britain and Northern Ireland', and this name encapsulates the countries England, Scotland, Wales and Northern Ireland.

The term 'Great Britain' just refers to the countries of England, Wales and Scotland, and so shouldn't be used interchangeably with 'UK'. The term 'British Isles' is just a geographical term and refers to England, Wales, Scotland, Northern Ireland, the Republic of Ireland, and thousands of smaller islands including the Channel Islands off the coast of France and the Isle of Man, but is not used when referring to nationality. **EC**

Ensure you know which nations you're referring to next time you say 'UK' or 'Britain'



New Brain Dump is here!

Don't miss issue 33 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 4 February. You'll find out why onions make our eyes water, why touchscreens don't work with gloves, and the answer to the question: why are slugs attracted to beer? You'll also discover the life cycle of a seahorse, why sea water is salty, and much more! Every edition is packed with fun facts to entertain your friends and family with. Download the new issue of **Brain Dump** at the beginning of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BrainDumpMag** or Twitter – the handle is **@BrainDumpMag**.

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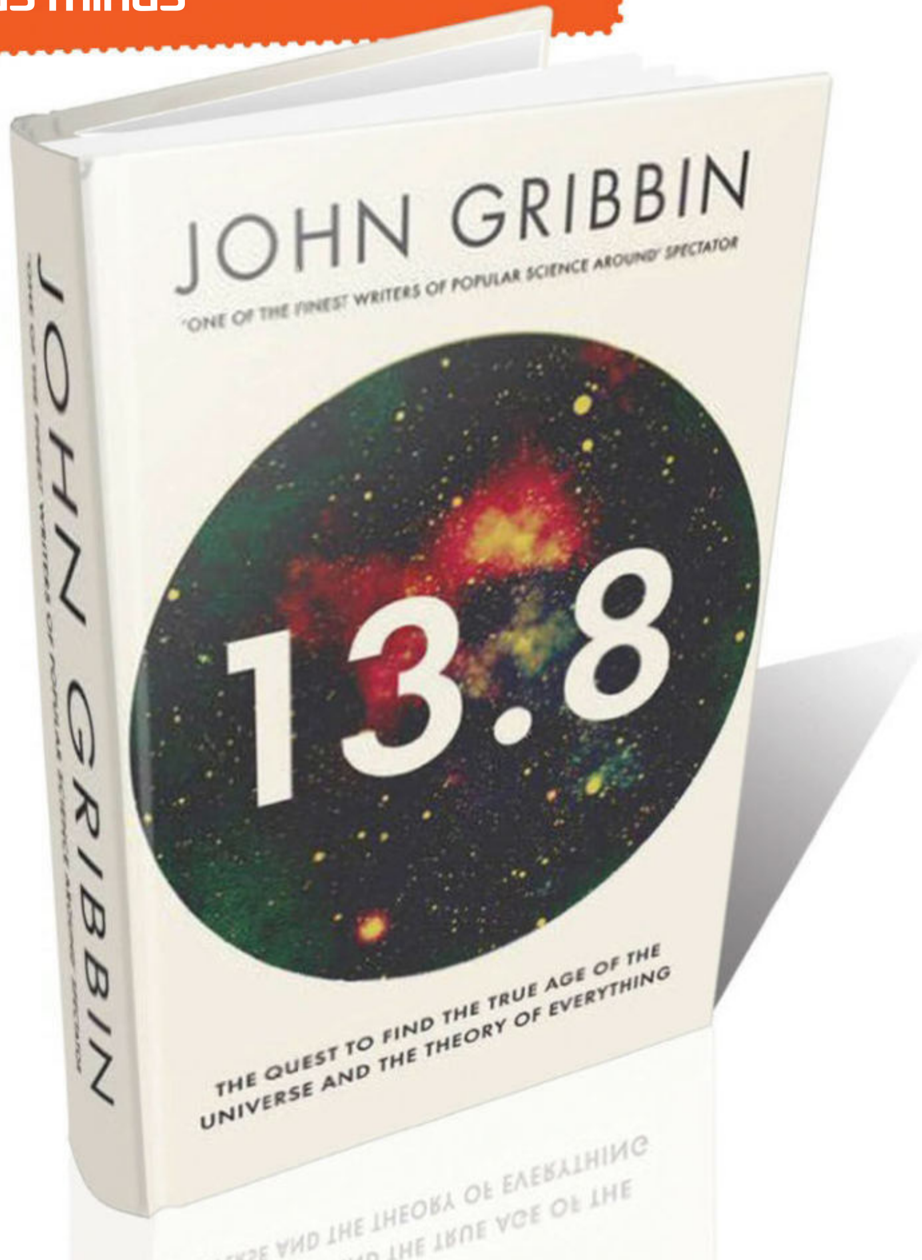
BOOK REVIEWS

The latest releases for curious minds



13.8: The Quest To Find The True Age Of The Universe And The Theory Of Everything

How we know the universe's birth date

- Author: **John Gribbin**
- Publisher: **Icon Books**
- Price: **£16.99 / $30**
- Release date: **Out now**

For us, keeping track of our age is as simple as counting the candles on a cake, but for the universe it is a little more complicated. It has taken some of the world's greatest physicists decades to work out the true age of our galaxy's home, but in 2013 they finally settled on 13.8 billion years – for now at least. In his latest book, British astrophysicist John Gribbin tells the incredible story of how this discovery was made. He argues that it's one of humankind's greatest achievements, which could lead us to the Holy Grail of physics – a unified 'Theory of Everything'.

As an established popular science writer, Gribbin provides an engaging narrative, beginning with the quest to find the age of stars and then exploring the people and instruments that helped to date the universe. Although he manages to break down most of the meaty science into manageable explanations, complete novices may find themselves lost among the jargon and equations. The story also feels dry in places, with a lack of description that could really bring the people and places involved to life. However, with so much ground to cover, the author can be forgiven for getting straight to the point, and the book does include photographs of the key players.

It is somewhat frustrating, especially given the lack of embellishment, that Gribbin chooses to include frequent references to his own involvement in the story. While this does help to instil confidence in the validity of his knowledge, it doesn't add much for the reader's understanding or entertainment. In addition, the ending to the book feels like it could have gone further, as it draws the story to a satisfactory conclusion but leaves little inclination as to what comes next.

For existing fans of Gribbin's writing, this book is a comprehensive guide to modern physics and its achievements, but for those who are new to his popular science books, this is not the best introduction.

YOU MAY ALSO LIKE…

Seven Brief Lessons On Physics

Author: **Carlo Rovelli**
Publisher: **Allen Lane**
Price: **£9.99 / $18**
Release date: **Out now**

A simple yet enchanting introduction to modern physics that manages to swiftly explain general relativity, quantum mechanics, black holes and more, in under 80 pages.

The Universe In Your Hand

Author: **Christophe Galfard**
Publisher: **Macmillan**
Price: **£14.99 / $27.99**
Release date: **Out now**

Take a fascinating and humorous journey through space, time and beyond to get to grips with how the universe began and where humanity is headed, in this lively and easy-going book.

Human Universe

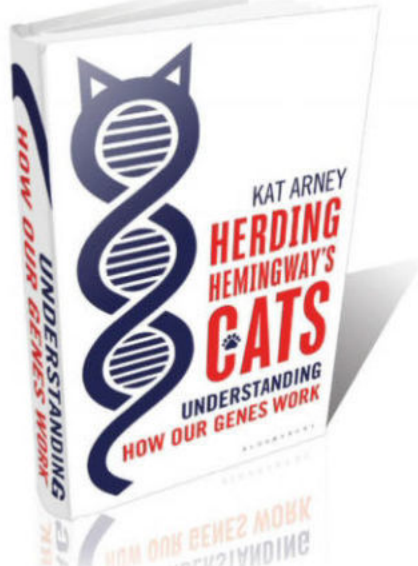
Author: **Professor Brian Cox**
Publisher: **William Collins**
Price: **£8.99 / $16.99**
Release date: **Out now**

Based on the BBC Two series of the same name, one of Britain's best-loved scientists ponders the origins of humanity, our destiny and our place in the universe with a sense of wonder and his usual infectious love for science.

Herding Hemingway's Cats

How your genes make you who you are

- Author: **Kat Arney**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $27**
- Release date: **Out now**



The colour of your eyes, the curliness of your hair and even the shape of your nose are all determined by genes, but do you know how they really work? *Herding Hemingway's Cats* explains how our genetic code is translated into both visible and hidden traits in our bodies.

Injecting personality, enthusiasm and humour into the topic, geneticist Kat Arney uses bizarre stories, such as that of Ernest Hemingway's six-toed cats – the inspiration for the book – to show how genes give our cells the recipe for life. Exploring the dynamic code of our DNA, she also shows how genes are switched on and off, and how gene-based advances in medicine hold huge promise for the future of humanity.

The Complete Guide To Drones

Meet an army of high-tech UAVs

- Author: **Adam Juniper**
- Publisher: **ILEX**
- Price: **£14.99 / $19.95**
- Release date: **Out now**

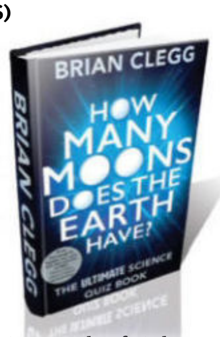
With consumer drones really taking off, more and more books relating to these trendy UAVs are landing on the shelves. This beginner-friendly guide provides a huge amount of information, ranging from how the various designs work to choosing the right drone for you.

The jargon-free language and enthusiastic tone makes the book easy to get onboard with, and the text is accompanied by an interesting array of photographs and illustrations. If you're already well-versed in the workings of modern drones this might not teach you anything new, but for those of you thinking about making your first drone-related purchase, this book will provide you with all you need to know.

How Many Moons Does The Earth Have?

The ultimate science quiz book

- Author: **Brian Clegg**
- Publisher: **Icon Books**
- Price: **£8.73 / $12.95**
- Release date: **Out now (UK) / June 2016 (US)**



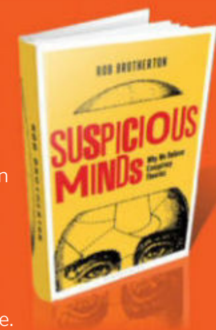
If you're not a fan of the questions in a general knowledge quiz and want to focus on testing your science, this book may well provide a solution. It contains two quizzes, each with six rounds of eight questions, plus two 'special rounds' containing themed questions.

There's an explanation provided with each question, helping you learn more than just the right answer. This isn't one for younger readers, as the questions are tricky, but for science-loving teens and adults, it's an enjoyable challenge. Even the most science-literate may well be left scratching their heads!

Suspicious Minds

Why conspiracy theories suck us in

- Author: **Rob Brotherton**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $27**
- Release date: **Out now**

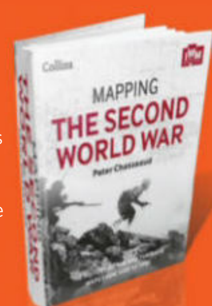


They provide the plots for Hollywood blockbusters and suggest solutions for countless crimes, but this book focuses on why we're suckers for a good conspiracy. Rather than examining specific theories – although plenty get a mention – this book focuses on the thinking behind them, specifically how we decide what is ridiculous and what is perfectly reasonable. The book explains how our brains are wired and why we believe anything at all, not just conspiracies. It's exceptionally well researched, using the latest scientific studies to provide an accessible insight into why we're drawn to implausible theories. It's an enlightening and educational read.

Mapping The Second World War

The events of the war told through military maps

- Author: **Peter Chasseaud**
- Publisher: **Collins**
- Price: **£30 (approx $45)**
- Release date: **Out now**



The story of WWII has been told countless times, but not many will have learnt it through the maps created during the conflict. From the invasion of Poland to the D-Day landings, this book shows a huge selection of original maps from the time, complete with hand-written annotations and an accompanying explanation of the events. For any WWII aficionado this is an excellent read, providing detail that many books struggle to deliver. As they have been shrunk to fit the pages, many of the maps are difficult to read with the naked eye. Keep a magnifying glass to hand to get the most out of this brilliantly informative book.

The Final Few

Meet the pilots who survived the Battle of Britain

- Author: **Dilip Sarkar**
- Publisher: **Amberley**
- Price: **£16.99 / $26.95**
- Release date: **Out now**

Arguably one of the most important events in British history, The Battle of Britain kept Hitler's army and the Luftwaffe at bay. Facing overwhelming odds, Britain's pilots produced a victory that would prove crucial in winning the war. This book is packed full of recent interviews with surviving pilots, providing brand new detail on the events during the summer of 1940. These are the real highlight, but there is also a short, concise summary of what happened during The Battle of Britain, which puts into context just how unlikely an Allied victory was. It's an addictive read, and may well be the final accounts from some of the heroes who protected the nation over 75 years ago.

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Brew your own beer

With a basic kit and a few ingredients, you can brew a boozy beverage at home

1 Make raw beer

To make your raw beer – known as wort – place crushed barley grains in a grain bag and steep it in water at 70 degrees Celsius. Leave the bag to soak for around 30 minutes. This breaks down the grain's starches into sugars, producing a malt extract. You will notice the water gradually turning a brown colour. When the time is up, remove the grain bag, top up your pan with water, and bring it back up to the boil.

2 Finish the wort

Add the bitter hops into the boiling water, which work to balance out the beer's sweetness with their flavour. Wait 45 minutes before adding any flavouring hops, and then add finishing hops once the pot has boiled for an hour. You then need to chill the wort to around 20 degrees Celsius by placing the pan in an ice bath. Next, sterilise a separate plastic container, which will be used to ferment the wort.

3 Add the yeast

Strain the wort into a fermenting container and place a hydrometer inside, making a note of the initial reading. Add a sachet of yeast, stir and then replace the airtight lid. Leave the mixture to ferment for five to seven days, at a temperature of 21 to 27 degrees Celsius. In this time, the yeast will break down the sugar into carbon dioxide, which makes the beer fizzy, and ethanol, which provides the alcohol content.

4 Check the beer's gravity

To check whether the fermentation process is complete, you need to examine the reading on the hydrometer. This measures the specific gravity of the liquid, which should gradually drop as the yeast converts more and more of the sugar into alcohol. Remember to calibrate your hydrometer to the temperature of your liquid. A reading of around 1.010 will indicate that the fermentation process is complete.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

5 Bottle your beer

Add some priming sugar (sugar dissolved in water) to your empty bottles, which will help the beer to remain fizzy. Next, siphon it into a separate bucket, and add more sugar to the beer before you start bottling it. Once you begin this process keep the flow going. If you don't, you'll add some of the liquid's frothy sediment to the bottle, which ruins the taste. Secure the caps with a bottle capper, and leave them for a few weeks in a dry place before sampling your beer!

In summary...

In the fermentation process, the yeast converts sugar into carbon dioxide and alcohol, to the point where the alcohol content actually kills the yeast. Amazingly, versions of this technique have been used for thousands of years, yet we've only known about microbes for a few centuries!

NEXT ISSUE
- Build a projector with a smartphone
- Make a fog machine

Make hot ice

Use the science of supercooled liquids to build your own ice tower

Illustrations by Edward Crooks

1 Dissolve the sodium acetate
Grab a non-stick pan and half fill it with cold water, then place it on the hob and bring it to the boil. Slowly pour sodium acetate powder (available online or in shops) into the pan, and immediately start stirring with a wooden spoon to help it dissolve in the water. Make sure you are wearing an oven glove when you do this, to prevent any spitting water from burning your hand. Keep adding the powder until no more will dissolve.

2 Chill in the fridge
Once you've dissolved as much as you can, take the pan off the heat and cover it immediately to prevent further evaporation from occurring. When the solution has stopped bubbling and you feel comfortable handing it, gently pour it into a glass container and cover it again. Do not wash away any solid sodium acetate that is left at the bottom of the pan, as this might be required in the next step. Place your glass in the fridge, and leave it to cool.

3 Build your tower
When your solution has chilled for a couple of hours, take it out of the fridge. Slowly pour the liquid onto a small plate, drip by drip if you can, and watch what happens. The solution should instantly go from a liquid to an ice-like solid, giving out heat as it does so. With some careful pouring, you can build 'hot ice' towers several centimetres tall! You can also try adding some of the solid sodium acetate from your pan, which should cause the whole liquid to crystallise.

In summary...
Once the sodium acetate solution has been in the fridge it becomes supercooled – a state where a liquid does not solidify below its freezing point. When you pour this supercooled liquid an exothermic reaction occurs, which means heat is released as the solution crystallises and the 'ice' is created. This type of reaction is how many simple hand warmers work.

INBOX
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WIN!

We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!

DISCOVER ASTRONOMY WITH THE KNOWLEDGE: STARGAZING

Part of a series of brilliantly informative books, *Stargazing* gives an overview of our Solar System, and helps you to see it for yourself.

Letter of the Month

Planetary rings

Dear **HIW,**

I really love your magazine – I've been getting it for a few years now! I've always wondered what a planet's rings are made up of, and why doesn't Earth have them?

Thanks,

Jacob Samson (aged 13)

Great question, Jacob! The most famous planetary ring in our Solar System belongs to Saturn. This large disc is made up of a bunch of smaller rings, each composed of bits of rock, dust and ice, ranging in size from a grain of sand to chunks as big as a house. There are two theories to explain how Saturn's rings came to exist. The first suggests that as the planet was forming, some of the debris and dust that was merging to form Saturn wasn't pulled all the way in, and was left floating in orbit. A second theory proposes that the rings are remnants of several moons that once orbited Saturn, which got too close and were ripped apart by tidal forces created by the planet's gravity. Scientists believe that Earth once had its own ring made up of the same components as Saturn's, but this debris then combined to form our Moon.

In 1979, the Voyager 1 probe discovered that Jupiter also has rings, composed mostly of dust.

Saturn's rings are roughly 282,000 kilometres across but only around one kilometre thick

Why is ice slippery?

Dear **HIW,**

I love reading your magazine every month, it keeps me entertained for hours with all of the interesting facts and great pictures! My question for you is what makes ice slippery? Thanks again for making such a wonderful magazine!

Elliot Bird (aged 14)

Thanks for getting in touch, Elliot! After more than 150 years of investigation, scientists still don't agree on why ice is so slippery. The current theory is that ice has very low friction due to a thin layer of liquid water that is always present on its surface. These water molecules are unstable as they are constantly moving over the ice in search of something to bind to. This moving, fluid layer is difficult to walk on, creating a slippery feeling underfoot.

Ice is one of the only slippery solids in existence, and can easily cause accidents

Battling spicy food

Dear **HIW,**

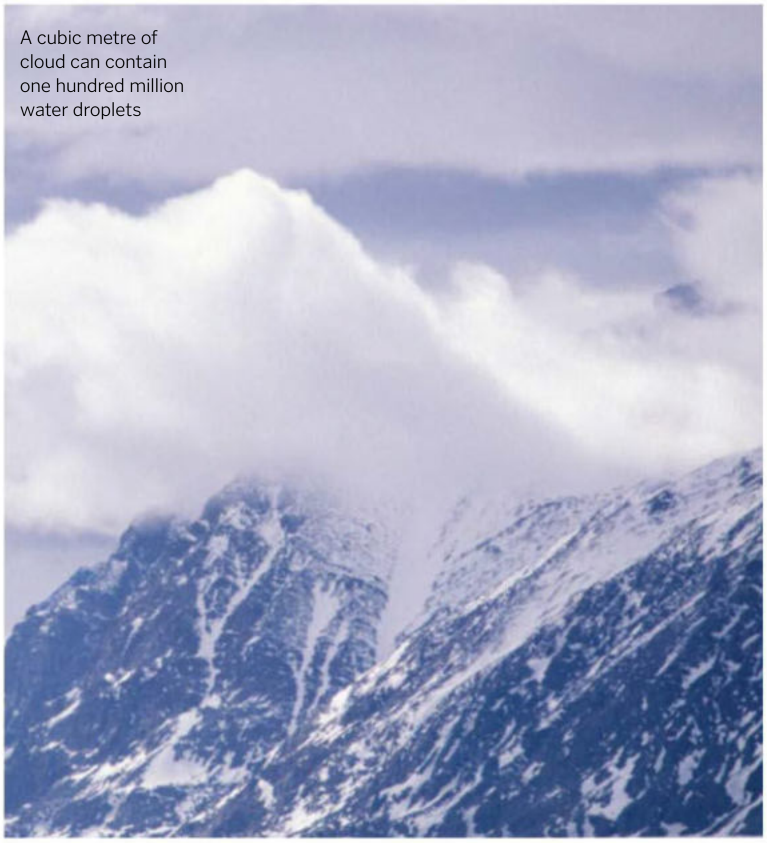
I was wondering what's the best way to cool your mouth down after eating something spicy?

Thanks,

Josiah Murphy

Capsaicin is the substance in chillies that is responsible for that spicy sensation. It binds to receptors in your mouth that normally detect heat, which is why spicy food can feel so fiery. To neutralise the burning sensation this produces, the best thing to drink is cold milk. This provides the fastest relief as it contains the protein casein, which breaks the bonds that capsaicin forms on your nerve receptors, relieving your mouth from the pain. Cold, strong alcoholic drinks will also work, as will sugar, especially if you combine it with dairy.

Don't reach for water, it will spread the heat rather than neutralising it



A cubic metre of cloud can contain one hundred million water droplets

Can clouds freeze?

Dear **HIW,**

I love your magazine and the new topics each month! I'd like to know if clouds can freeze, and if so, how does this happen? Thanks,

Jacob Maginn (aged 10)

Even when the temperature is below zero degrees Celsius, clouds actually don't freeze. This is thanks to a phenomenon called supercooling. If there are no other particles that the water droplets can crystallise around (called an ice nucleus), they are unable to freeze. Some of the water droplets in a cloud will remain liquid down to -40 degrees Celsius. If supercooled water droplets fall as rain, they will freeze as soon as they come into contact with another object, forming a layer of ice on roads, buildings and other surfaces.

> "Some water droplets in a cloud will remain liquid at -40°C"

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@finsmumma
@HowItWorksmag Latest issue just arrived, son is very happy, won't hear a thing out of him for a while!

@Jackieivylouise
Got the **@HowItWorksmag** Book of Incredible History the other day, love it, please keep them coming!

@SuperDaddyOfTwo
@HowItWorksmag thank you for my magazine prize, your mag is by far the best I have ever read! Wow!

@ezziemakeup
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@ScienceQuotes2
In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual – Galileo Galilei

@WorldClassFacts
A burning candle creates 1.5 million tiny diamonds per second!

@neiltyson
There are no right or wrong opinions, unless you have invalidated yours for having ignored facts that conflict with them.

@Corps_of_Oa
@HowItWorksmag when you get a song stuck in your head it's called an earworm, which forms because your brain didn't register the end and can't leave things unfinished! #science

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- Inside the Lockheed U-2 spy plane
- Tracking stealth submarines

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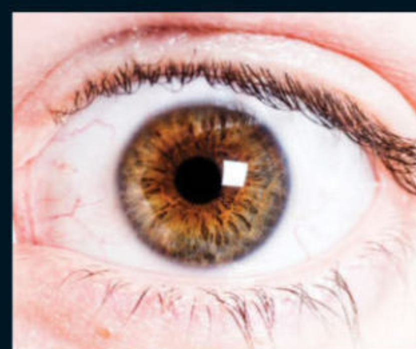

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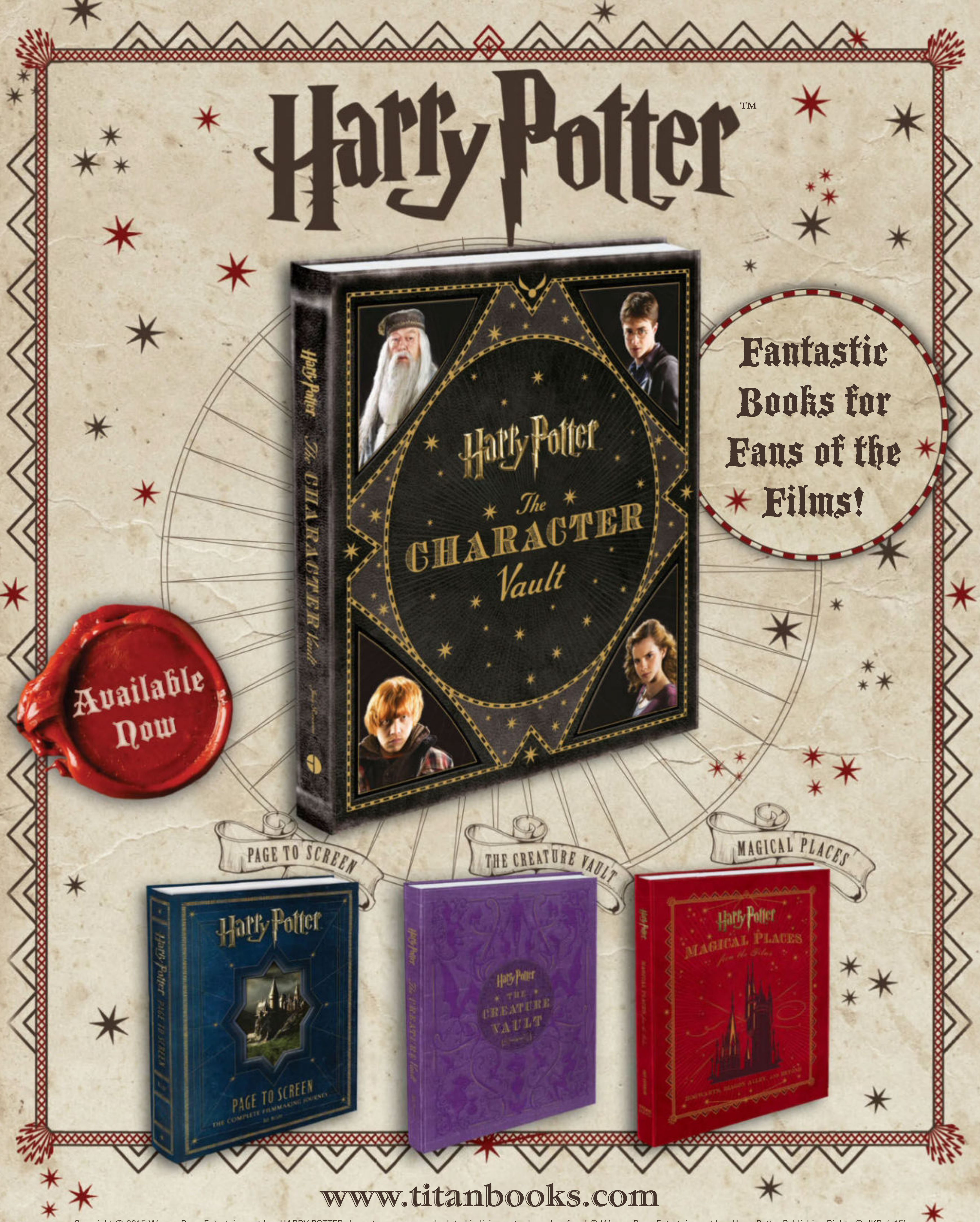
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